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RADC-TR-66-606, Volume III  
Final Report



HIGH VOLTAGE POWER LINE SITING CRITERIA  
Volume III. Bibliography

W. E. Pakala  
E. R. Taylor, Jr.  
R. T. Harrold

Westinghouse Electric Corp.

TECHNICAL REPORT NO. RADC-TR-66-606  
March 1967

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RADC (EMLI), GAFB, N.Y. 13440

Rome Air Development Center  
Research and Technology Division  
Air Force Systems Command  
Griffiss Air Force Base, New York

## HIGH VOLTAGE POWER LINE SITING CRITERIA

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APPENDIX VII

BIBLIOGRAPHY ON RADIO INTERFERENCE-  
HIGH VOLTAGE POWER LINES

This bibliography is in five parts as follows:

PART 1. FOREIGN LITERATURE 1959 TO 1966

The literature here is in abstract form and listed chronologically under the country of origin, title first.

Also included is an author index arranged alphabetically and a subject index.

PART 2. AMERICAN LITERATURE 1960 TO 1966

This is in abstract form and arranged alphabetically by means of the author's name.

Included is an author index arranged alphabetically and a subject index.

PART 3. AMERICAN LITERATURE PRIOR TO 1960

Here the literature is mainly in abstract form and arranged alphabetically by means of the author's name.

PART 4. SUPPLEMENT TO FOREIGN LITERATURE - ARRANGED NUMERICALLY

PART 5. SUPPLEMENT TO AMERICAN LITERATURE - ARRANGED NUMERICALLY

If an abstract that is indexed in either Part 1 or 2 cannot be found then refer to additions, Parts 4 and 5.

AIR FORCE CONTRACT A.F. 30-602-3822 - VOL. III

APPENDIX VII PART (1)

RADIO INTERFERENCE - HIGH VOLTAGE POWER LINES

FOREIGN LITERATURE 1959 TO 1966

The literature is in abstract form and listed chronologically under the country of origin, title first. See page 1.

Pages iv and v include an author index arranged alphabetically and on pages vi, vii and viii there is a subject index.

On page iii the reference numbers are indexed under the country of origin.

# RADIO INTERFERENCE - HIGH VOLTAGE POWER LINES

## FOREIGN LITERATURE 1959 TO 1966

### INDEX BY COUNTRY OF ORIGIN

	1959	1960	1961	1962	1963	1964	1965-66
Australia		1, 1A					
Belgium	2						
Canada	3				3A	4	4A
Denmark	7						7A
Egypt						8	
England	9, 10 9A (1949)	11	12, 13	14, 15	16	17, 18	
Finland				19		20	
France		21	22	23, 24, 25, 26, 27, 28	29, 30, 31	32, 33, 34, 35, 35A	
Germany	36	37, 38	39, 40	41, 42	43	44, 45, 46, 47, 48, 49	49A
Italy	50	51		52, 53	54	54A, 54B, 54C, 54D	
Japan	55, 56	57, 58, 59	60, 61, 62, 63	64, 65, 66, 67	68, 69	70	70A, 70B, 70C
Mexico						71	
Russia	72	74, 75, 76, 77, 77A		78	79, 80, 81	82, 83, 83A	
Sweden	84	84A		85		86	
Switzerland					87, 88, 89, 90		

RADIO INTERFERENCE - HIGH VOLTAGE POWER LINES

FOREIGN LITERATURE 1959 TO 1966

AUTHOR INDEX

AUTHOR	REF.NO.	AUTHOR	REF.NO.	AUTHOR	REF.NO.
Abetti, P.A.	14	Britton, G.A.	16	Gary, G.	30, 31
Aigner, V.O.	24	C.R.		Gion, L.	2
Akao, Y.	58, 63, 65	Cappuccini, F.	50	Gosland, L.	22
Akazaki, M.	3A	Clade, J.	29	Heintz, W.	36
Akopyan, A.A.	82	Clark, C.H.W.	9	Hylten-Cavallius, N.	28, 33
Amemiya, Y.	61	Curcuruto, A.	52		
Baer, K.V.	37	De Bernochi, C.	54	Iliceto, F.	34
Ball, A.H.	12	Dembinski, E.M.	15	Jensen, V.	7
Bartenstien, R.	21, 26, 32, 42	Dennhardt, A.	49	Jones, D.E.	4A
Barthold, L.O.	23	Denholm, A.S.	3	Kafieva, K.Ya.	76
Baumann, E.	43	Enjoji, H.	56, 57	Kageyama, Y.	60
Berger, K.	87	Feist, K.H.	47	Karamzin, A.P.	80
Borelli, F.B.	71	Frommer, E.	46	King, S.Y.	10
Burgsdorf, V.V.	83A, 77A	Fromy, E.	35	Kino, J.	55
Brasca, E.	53	Furmanov, I.M.	75	Klewe, H.	48
				Knudson, N.	86

RADIO INTERFERENCE - HIGH VOLTAGE POWER LINES

FOREIGN LITERATURE 1959 TO 1966

AUTHOR INDEX

AUTHOR	REF.NO.	AUTHOR	REF.NO.	AUTHOR	REF.NO.
Kohoutova,D.	6	Poltier,L.	89	Varshney,M.P.	17
Larsson, O.	85	Popkov,V.I.	5,81	Venchkovskii, L.B.	77
Larsson, N.	20	Rogers,E.C.	11		
Lorenz, H.	38	Sajonz,J.	39,40	Warner, A.	49A
Malakhov,A.M.	72	Sarapkin,V.V.	79	Whitehead,S.	9A
Meister, E.	88, 90	Saruyama,Y.	70A	Witt, H.	84A
Morris, R.M.	4	Sawada, Y.	64,67, 70C	Yamada, T.	59, 70
Orlov, V.N.	78				
Ortloff, M.	41	Sato, Y.	62	Yamaguti,T.	68
Paris, L.	51	Sforzini,M.	54A,B, C&D	Zaazou, A.	8
Paimoeuf,M.	25				
Pedersen, A.	7A	Smirnov,B.V.	74		
Pellissier,R.	27	Sporn, Ph.	21A,35A		
Perelman,L.S.	83	Takasu,N.	66,69		
Personen,A.J.	19	Thebridge,F.A.	1		
Petterson,G.A.	84	Thomas,D.R.W.	13		
Pfaler,E.Von	44, 45	Thornton,J.G.	1A		
		Udo, T.	70B		



# RADIO INTERFERENCE - HIGH VOLTAGE POWER LINES

## FOREIGN LITERATURE 1959 TO 1966

### SUBJECT INDEX

THEORY AND LABORATORY MEASUREMENTS		INSTRUMENTATION AND MEASUREMENT		A.C. LINES		D.C. LINES		LINE ANALYSIS AND COMPONENTS	
(a) <u>LABORATORY</u> <u>R.I.</u> <u>MEASUREMENTS</u> 30, 56, 43, 54A, 54C	(a) <u>RECORDING</u> <u>INSTRUMENTS</u> 7, 15, 90, 3, 75, 72, 24, 61, 38, 3, 13, 18, 95	(a) <u>CORONA AND</u> <u>R.I.</u> 22, 27, 62, 14, 15, 35A, 6, 26, 60, 70, 20, 77A, 31, 37, 63, 73, 59, 84A, 57, 56, 55, 36, 54A, 5, 76, 24, 74, 77, 37, 7, 23, 72, 51, 9, 40, 13, 23, 54B, 70A, 70C, 7A, 35, 45, 83A, 87, 17, 82, 86, 8, 43, 80, 1A, 21A	(a) <u>AC/DC</u> <u>COMPARISONS</u> 58, 5, 8, 84A	(a) <u>VOLTAGE</u> <u>GRADIENT</u> 55, 17, 10, 33, 21, 81, 4, 54A, 70C, 7A					
(b) <u>METHODS OF</u> <u>CALCULATING</u> <u>R.I.</u> 43, 59, 21, 27, 79, 32, 44, 78, 45, 83, 23, 39, 77, 33, 54D	(b) <u>TOLERABLE</u> <u>LEVELS</u> 12	(b) <u>CONVERTER</u> <u>STATIONS</u> 29, 28, 34	(b) <u>CONVERTER</u> <u>STATIONS</u> 29, 28, 34	(b) <u>CONDUCTOR</u> <u>DIAMETER</u> 71, 33, 76, 4					
(c) <u>THEORY OF</u> <u>R.I. FROM</u> <u>LINES</u> 27, 21, 43, 86, 44, 83, 36, 60, 65, 23, 77, 54D, 70B	(c) <u>SAMPLING</u> <u>METHODS</u> 7, 61, 24, 8, 54B, 77A, 21A, 4A	(c) <u>CORONA AND</u> <u>R.I.</u> 81, 28, 58, 33, 54, 4, 5, 8, 3A, 84A	(c) <u>CORONA AND</u> <u>R.I.</u> 81, 28, 58, 33, 54, 4, 5, 8, 3A, 84A	(c) <u>LINE CON-</u> <u>FIGURATION</u> 4, 10, 55, 76, 59, 83A, 17, 21, 86, 32, 3A, 70C					
(d) <u>MEASUREMENT</u> <u>OF LINE</u> <u>CHARACTERISTICS</u> 32, 84, 78, 35A	(d) <u>INSTRUMENT</u> <u>ERROR</u> 3, 75	(d) <u>HARMONIC</u> <u>FILTER FOR</u> <u>HV DC SYSTEM</u> 34	(d) <u>HARMONIC</u> <u>FILTER FOR</u> <u>HV DC SYSTEM</u> 34	(d) <u>INSULATOR</u> <u>HARDWARE</u> <u>R.I.</u> 30, 18, 2, 85, 87, 9, 74, 31, 79, 3, 37, 54A, 54C, 70A, 70B					
	(e) <u>AUTOMATED</u> <u>MEASUREMENTS</u> 18, 42, 95, 4A	(e) <u>STATISTICS ON</u> <u>LINE FAILURE</u> 89, 21A	(e) <u>STATISTICS ON</u> <u>LINE FAILURE</u> 89, 21A	(e) <u>CONTAMINA-</u> <u>TION</u> 2, 33, 56, 8, 1A, 84A					
	(f) <u>R.I. SURVEYING</u> 13, 55, 90, 4A								

# RADIO INTERFERENCE - HIGH VOLTAGE POWER LINES

FOREIGN LITERATURE 1959 TO 1966

## SUBJECT INDEX

THEORY AND LABORATORY MEASUREMENTS	INSTRUMENTATION AND MEASUREMENT	A.C. LINES	D.C. LINES	LINE ANALYSIS AND COMPONENTS
(e) <u>REPEATED PULSES ON LINES</u> 69, 57, 66	(g) <u>INSTRUMENT COMPARISONS</u> 12, 24	(e) <u>COMPLAINTS</u> 88, 89, 16		(f) <u>FOUL WEATHER EFFECTS</u> 3A, 83A, 67, 62, 6, 4, 55, 56, 89, 86, 33, 20, 81, 77A, 54B, 1A, 84A 70B
(f) <u>HARMONICS</u> 9A	(h) <u>LOCATING SOURCE OF R.I.</u> 80, 61	(f) <u>CONDUCTOR AGEING</u> 67, 83A, 84A		(g) <u>TRANSFORMERS, ETC.</u> 53, 66, 50, 74, 29, 24
(g) <u>CORONA STARTING VOLTAGES</u> 7A	(i) <u>SPECTRAL ANALYZER OF LOW FREQUENCY NOISE</u> 72	(g) <u>COUPLING</u> 84, 39, 24, 60, 40, 47, 52, 19, 59, 68, 48, 3, 43		(h) <u>NOISE GENERATORS</u> 4, 70B
(h) <u>GROUND REFLECTIONS</u> 49A		(h) <u>RADIO AND TELEVISION INTERFERENCE</u> 69, 18, 16, 36, 7, 1, 77A		(i) <u>CORROSION</u> 66
		(i) <u>LINE INTERSECTIONS</u> 59, 60, 19		(j) <u>PROLONGED DRY WEATHER</u> 67, 86
				(k) <u>HUMIDITY EFFECT ON R.I.</u> 86, 8, 55, 3A, 77A, 54B

# RADIO INTERFERENCE - HIGH VOLTAGE POWER LINES

FOREIGN LITERATURE 1959 TO 1966

## SUBJECT INDEX

<u>THEORY AND LABORATORY MEASUREMENTS</u>	<u>INSTRUMENTATION AND MEASUREMENT</u>	<u>A.C. LINES</u>	<u>D.C. LINES</u>	<u>LINE ANALYSIS AND COMPONENTS</u>
		(j) <u>TRANSMISSION OF RADIO PROGRAM OVER POWER LINE</u> 58, 4A		(1) <u>SITING OF RADIO DIRECTION FINDER WITH RESPECT TO MEDIUM VOLTAGE LINE</u> 46
		(k) <u>PROBABILITY OF INTERFERENCE</u> 13, 23		
		(l) <u>REDUCTION, PREVENTION AND SUPPRESSION OF R.I.</u> 86, 81, 21, 39, 85, 7, 5, 64, 53, 65, 85, 29, 59, 35, 34, 3, 69, 28, 41, 87, 88, 16, 49, 57, 35A, 37, 40, 58, 1, 5, 64, 9		
		(m) <u>MEDIUM VOLTAGE LINES</u> 66, 85, 31, 79, 74, 77, 31		
		(n) <u>HARMONICS IN TRANSMISSION LINES</u> 9A		

## SECTION A

### RADIO INTERFERENCE - HIGH VOLTAGE POWER LINES

#### FOREIGN LITERATURE 1959 TO 1965 (JULY)

##### AUSTRALIA

###### 1960

1. Interference Suppression in Household Appliances.  
Thebridge, F.A.  
Paths by which interference arrives at radio and television receivers; design and application of interference suppression capacitors, including star, delta and series, single winding types; combination of capacitors and inductors into line filter and proper use of filter.  
Institution of Radio Engineers.  
Australia Proc.  
Volume 21, n9,  
September 1960,  
Pages 577-80.
- 1A. The 330 kV Transmission System in Australia.  
Thornton, J.G.  
CIGRE Paper 401  
June 1960

##### BELGIUM

###### 1959

2. Evolution de la technique des isolateurs en ceramique.  
Gion, L.  
Development of ceramic insulator technology; discussion includes new ceramic materials, such as Durelcer and designs of insulators such as Spirelec, as well as contamination and radio interference problems.  
Societe Belge des Electriciens.  
Bul. Volume 75, ni  
January-March 1959,  
Pages 29-38.

## CANADA

### 1959

3. Radio Noise Testing of High Voltage Line Equipment.

Denholm, A.S.

Facilities for noise testing at National Research Laboratories and methods adopted to minimize interference from test equipment itself; two simple noise measuring circuits which compensate for stray and coupling capacitance.

Engineering  
Institute of  
Canada. Trans.  
Volume 3, No. 1,  
April 1959,  
Pages 13-17.

### 1963

- 3A. Corona Phenomena from Water Drops on Smooth Conductors Under High Direct Voltage.

Akazaki, M.

National Research  
Council of Canada.  
Ottawa, Canada,  
November 1963.

### 1964

4. Work of the National Research Council of Canada on Corona and Radio Interference in High Voltage D.C. Systems.

Morris, R.M.

An extended summary is given of two reports issued by the councils Radio and Electrical Eng. Division. Corona loss measurements were made on a single steel-cased aluminum conductor of 1.108 in. diameter and on a twin conductor bundle of the same size, with 18 inch spacing. An inner insulated wire in the conductor enabled conductor losses to be measured independent of other losses. Voltage increment tests were made in steps of 50 kV from 20 to 500 kV d.c., positive and negative, and during constant weather conditions. Losses were also measured with the lines at constant voltage in varying weather conditions. Radio interference characteristics were measured with the

Direct Current (GB),  
Volume 9, No. 1,  
Pages 26-34,  
(February 1964).

lines at 300 to 500 kV d.c. under corona excitation, and under excitation by an oscillator, measurements were made at 0.2 to 10 Mc/s. The results are shown graphically. It was found that corona losses from each conductor configuration were higher under negative than under positive voltage. Only positive conductors produced radio interference in the frequency range studied.

#### CZECHOSLOVAKIA

1961

5. Otázky potlačování radiového narušení způsobeného Koronou.

Popkov, V.I.

Problems of suppression of radio disturbances caused by corona; radio interference carried by direct and alternating current, special features of disturbances in frequency range from 150 to 8800 Kc/s and their dependence on form of corona; most advantageous counter measures are seen to be special coating of conductor for negative corona and application of screening wires of small diameter for positive corona (English summary).

Elektrotechnický  
Obzor, Volume 50,  
No. 4, April 1961,  
Pages 185-191.

6. Measurement of Corona Losses and Determination of their Yearly Average on VHV Lines.

Kohoutová, D.

Describes 400 kV experimental line in Bechovice, consisting of bundled conductors of the type Al Fe and of 350 mm<sup>2</sup> cross section, results of corona loss measurement with an analysis of the climate conditions in the northern branch of Czechoslovakias 400 kV line are given. A relationship is shown for the calculation of the yearly corona loss.

Elektrotechnický  
Obzor  
(Czechoslovakia),  
Volume 52, No. 6,  
Pages 287-91 (1961)  
In Czech.

## DENMARK

1959

7. Radio Interference in the VHF Range.

Jensen, V.

Analysis of impulsive interference in VHF range, where in particular TV reception is exposed to disturbance by motorcar ignition interference and commutator interference from electrical appliances; methods of measuring interference voltages and interference fields originating from electrical machinery, results of laboratory measurements of various VHF interference suppressing components are reported and some methods of vhf commutator interference suppressions are stated.

Teleteknik  
(English Ed.)  
Volume 3, No. 1,  
1959, Pages 1-17.

## EGYPT

1964

8. Radio Noise due to Insulator Corona, Effect of Atmosphere Humidity and Other Factors.

Zaazou, A.

Radio noise due to corona discharges on suspension insulators is studied as influenced by atmospheric humidity, insulator--surface pollution and harmonic contents in the alternating voltage wave applied across the insulator. The radio-noise level is also measured under direct-voltage conditions. The tests were carried out in humidities between 10 and 38 mg/M<sup>3</sup> at temperatures, between 15°C and 38°C. Alternating voltages up to 45 kV are used with harmonic contents up to 40%, and direct voltages up to 70 kV are applied. The radio noise level is found to increase with the air humidity and decrease if the insulator is kept in a humid atmosphere for

Proc. Inst. Elect.  
Engr. (GB), Volume  
III, No. 5,  
Pages 959-66  
(May 1964).

sometime. The noise level with alternating voltages is found to be considerably higher than that with direct voltages of the same amplitude. It is found to be still higher if the alternating voltage wave contains third harmonic so as to be double-humped. The cement binding the metal cap and pin to the porcelain is found to be main source of radio noise when the insulator is under corona discharge.

#### ENGLAND

##### 1959

9. Radio Interference from HV Insulators

Clark, C.H.W.

Explains the mechanism of interference generation by high voltage insulators and the effect of insulator design on radio interference. The measurement of interference is considered and methods of overcoming the difficulties involved are discussed.

Electrical Review  
Volume 165, No. 11,  
Pages 491-7,  
October 23, 1959.

10. Electric Field Near Bundle Conductors

King, S.Y.

Analysis deals with single phase lines with bundles of two, three or four conductors, but it can be extended to cover any number of conductors in bundle: for 3 phase lines, resultant field can be found by principle of superposition when fields due to two or other phases are taken into consideration, formulas giving potential gradient at any point on conductor surface.

Institution of  
Electrical Engineers  
Proceedings,  
Volume 106, pt. C.  
No. 10, (Monograph  
N338)  
September 1959,  
Pages 200-6.



## ENGLAND

1960

11. Gaseous Discharge Phenomena in  
High-Voltage d.c. Cable Dielectrics.  
Rogers, E.C.

Proc. Institution  
of Electrical  
Engineers, 1960,  
107A, F. 241.

Considerations of the short-time electric strength and of the conductivity/temperature stress relationships show that both impregnated paper and polythene are likely to be satisfactory dielectrics for use in HVDC cables. From a.c. experience, however, it is known that polythene in particular is very vulnerable to damage caused by discharges in gas-filled cavities, and an assessment of the importance of this mode of deterioration under d.c. conditions is therefore necessary.

Calculations have been made of the repetition rate of discharges in a gas-filled cavity in a dielectric subjected to a d.c. stress, since this is clearly a decisive factor determining the rate of deterioration. The repetition rate is shown to be a maximum when the surface conductivity of the dielectric is zero. Direct measurements of the repetition rate of discharges are described, and the measured rates are shown to be consistent with the calculated maximum rates. The effects of ripple voltages and polarity reversals are considered.

From the predicted discharge repetition rates and from the results of accelerated life tests on samples containing cavities, a rough estimate of the effect of discharges on the probable life of an HV d.c. cable dielectric can be made. Polythene was selected as the example for study on account of its known vulnerability to discharges, and it is shown that with this material, discharge damage is unlikely to be a serious problem under d.c. conditions.

provided that ripple voltages are not excessive and that very frequent reversals of polarity can be avoided.

1961

12. Radio Interference from Ignition Systems.

Ball, A. H.

Comparison of American, German and British measuring equipment, techniques and limits, test conditions specified in various countries and limits of ignition interference recommended or statutory in countries concerned. Paper 3550E.

Inst. of Electrical Engrs. Proc., Volume 108, pt. B. (Electronic and Communication Eng.) No. 39, May 1961, Pages 273-8. See also Brit. Elec. and Allied Industries Research Assn.-Tech. Report M/T138, 1960, Page 15, Supp. Plate.

1961

13. Probabilities of Interference with Mobile Field Radio Derived from Field Strength Survey at 59 Mc/s.

Thomas, D.R.W.

Experimental investigation of common and immediately-adjacent-channel interference area based on field-strength survey over flat and hilly country, graphs on interference probability for practical use. 25 refs. Paper 3472E.

Inst. Electrical Engr.-Proc., Volume 108, pt. B. (Electronic and Communication Eng.) No. 39, May 1961, Pages 264-72.

1962

14. System Engineering Problems in EHV Transmission, Corona Loss, Radio Noise and Lightning Performance.

Abetti, P.A.

Corona loss, radio noise and lightning performance of EHV transmission lines are discussed from the system engineering viewpoint. Examples are given of methods employed to evaluate the significance of these factors in system design. Recent

CEGB Engr. Conference on Gas Discharges and the Electricity Supply Industry, Leatherhead, 1962 (see abstract 3511 of 1963), Pages 157-72.

knowledge, gained in these three fields during the planning and operation of project EHV is presented. It is concluded, that it is neither possible or economically sound to optimize each factor individually. Instead the interrelationships between the various factors and their effects on the total system cost and performance must be considered in order to achieve the optimum system.

#### 1962

15. Statistical Recording of Radio Interference from the Monk Fryston-High Marnham Line Run at 275 kV.

Preliminary results are presented of statistical measurements of radio interference at 55 Mc/s and 1.5 Mc/s taken of the Monk Fryston-High Marnham line. Details are given of the measuring equipment, together with relevant information on the 55-mile stretch of double circuit operational line on which both circuits are at present energized at 275 kV. Later this year one circuit will be run at 400 kV and comparison measurements taken. The levels measured directly under the lines were at no time excessive over the period May-December, 1961.

CEGB Conference on Gas Discharges and the Electricity Supply Industry, Leatherhead, 1962 (See abstract 3511 of 1963), Pages 282-8.

#### 1962

16. Effect of Transient, Fluctuating and Distorting Loads on Radio and Television Reception.

Britton, G.A.C.R.

The paper deals with each of the effects of transient, fluctuating and distorting loads on radio and television reception in turn. It is stated that the effect of transient loads takes the form of pulses of r.f. interference generated at discontinuities in the circuit. Such discontinuities may exist by intent, e.g. switches, contacts,

Inst. Elec. Engr. Conf. Rep. Ser. (GB) No. 8 3-5 (1964) (Abnormal loads on power systems London 1963).

contactors, and thermostats, or fortuitously by the physical nature of circuit components, e.g. commutators and brushes, gaseous discharge devices, surface leakage across high-voltage insulators or sliding contacts. The relative importance of the various kinds of transient interference is indicated by reference to the totals of complaints of interference received by the post office. Methods of measuring, assessing and suppressing the interference are touched on, and recommended limits are mentioned.

The effects of fluctuating loads on radio and television reception are seldom of great importance; they are, however, mentioned briefly. Finally the effect of distorting loads is considered, the example of interest being the mercury arc rectifier, which generates harmonics that may produce audio hum in radio reception and distortion of a television picture.

#### 1963

17. Balanced Corona Performance for Asymmetrical Three Phase Overhead Power Transmission Lines.

Varshney, M.P.

A.c. transmissions of larger blocks of power over larger distances has resulted in the use of progressively higher voltages, and the type of line conductors to be used then acquires increasing importance. For extra high voltage transmissions lines corona considerations result in the use of expanded AC SR; hollow copper conductors, or bundle conductors. For one conductor per phase, when corona considerations are the deciding design features, it may be desirable to design each phase separately, particularly for the commonly used flat horizontal configuration so as to bring the surface voltage gradient for each conductor down to the allowable value but no further.

International J.  
Elect. Eng.  
Education (GB),  
Volume 1, No. 3,  
Pages 345-9,  
March 1964.

Approximate expressions for surface voltage gradient are derived for the flat horizontal configuration.

1964

18. 800 kV Transmission Line Research at Leatherhead.

Engineer, Volume 217, No. 5653, May 29, 1964, Pages 949-50.

Experimental transmissions line was installed to enable Central Electricity Research Labs. to study insulators, fittings and conductors up to equivalent of 800 kV, 3 phase, continuous recording will be made of corona power loss and radio and TV interference; for this purpose statistical radio-interference recorder was developed; instrumentation also includes automatic corona loss bridge and data logger.

FINLAND

1962

19. Intersections Between Telecommunication Lines and Power Lines, with Reference to the Earth Fault Potential.

Pesonen, A.J.

The neutrals of the 110 kV, 220 kV and 400 kV systems in Finland are directly earthed. The earth fault currents are assumed to range between 0.5 and 3 kA. The degree of interference with telecommunication installations has been worked out.

Kraft O. Ljus (Finland), Volume 35, No. 11, Pages 292-6, (November 1962), In Swedish.

1964

20. Measurements of Corona Losses due to Hoar Frost and Water Precipitation on 400 kV. Operating Lines in Finland with special reference to Estimation of Hoar Frost Corona Losses Based on Meteorological data.

Conf. Intern. Grands Reseaux Elect. (CIGRE), France, 1964, Paper 409, Page 13.

Larsson, N.

Summarizes the measurements of corona losses on operating 400 kV lines in Finland made during three successive winter periods. The effect of the line current upon the layer which has been formed on the conductors has also been investigated. Finally a method is presented, which could be applied in estimating the winter corona losses on lines that are going to be constructed in the areas where hoar frost is likely to occur.

FRANCE

1960

21. Predetermination of the High-Frequency Level of High Voltage Transmission Lines.

Bartenstein, R.

The results gained by the 400 kV test station at Rheinau have made possible a fundamental description of the nature of interference phenomena. Beginning with the high-voltage transmission line as a source of Radio Interference, a definition is given of the interference quantity which makes it possible to describe the nature of interference with the aid of an equivalent circuit diagram. The factors influencing this interference quantity are also studied, a distinction being made between those which can be controlled by varying the line configuration and those which cannot be readily controlled. The measurement of these variables is described. From all investigations so far carried out it can be seen that there is a general correlation between the surface field gradient and interference field intensity at least for bundled conductors. Once the correlation between the surface field gradient and interference field intensity and the equivalent circuit diagram for interference phenomena is known the line RI level may be calculated.

Conf. Intern.  
Grands Reseaux  
Elect. (CIGRE)  
(France) 1960,  
Pages 409-411.

FRANCE

1960

- 21A. Report on the Work of Study Committee No. 9 on Extra-High Voltage A.C. Transmission.

CIGRE Paper 416,  
June 1960

Sporn, Ph.

Discusses economic aspects of Extra-High Voltage transmission. Fault statistics RI measuring in different countries with the same meter.

1961

22. Report on the work of Study Committee No. 11 Radio and Telephone Interference. Gosland, L.

(CIGRE) France,  
Paper 329, Page 14,  
(1962).

Study committee No. 11 met in Paris on June 1960 and in Arizona in April 1961. This report notes the principal matters discussed by the committee, and presents, in appendices, preliminary information on some of the topics of major interest at present which has been contributed by members of the committee.

1962

23. Some Important Assumptions in Calculation of Radio Noise Levels of EHV Lines.

Barthold, L.O.

Extension of prior analytical methods of predicting radio noise levels caused by random corona discharges on ehv transmission lines, evaluation of noise generation on power spectral density basis, and propagation and treatment of corona pulses by means of eigen value analysis, effects of line length.

Conference Int. des  
Grand's Reseaux  
Electrique a Haute  
Tension 19th  
May 16-26, 1962,  
Cr No. 303, Page 12,  
CIGRE.

FRANCE

24. Corona Detection in Transformers.  
Aigner, V.O.  
Report on behalf of int. study committee, necessity of standardization or at least gaging of different measuring instruments and their coupling on same base; inner corona and its possible effects; methods of testing corona intensity, corona-behavior and life span of transformers; permissible corona for transformers, test methods.  
Conference Int. des Grands Reseaux Electrique on Haute Tension 19th, May 16-26, 1962, CRN 145, Page 20, CIGRE.
25. Special Report for Group 35 (Radio and Telephone Interference).  
Paimoeuf, M.  
Conf. Int. Grand Reseaux Elect. (CIGRE) (France) Spec. Report Group 35, Page 4.

1962

26. Radio Interference on Bundle Conductor Lines.  
Bartenstein, R.  
Gives a survey of Radio Interference Measurements on bundle conductors carried out on test and operating lines, states the results gained to date and makes recommendations for further investigations.  
CEGB Conference on Gas Discharges and the Electricity Supply Industry Leatherhead, 1962, (See abstract 3511 of 1963), Pages 307-10.



FRANCE

1962

27. Basic Principles for Radio Noise Calculations on EHV Transmission Lines.

Pelissier, R.

The present state of the theory of generation and the propagation of RI on EHV lines is reviewed. Certain refinements are put forward and the consequences of their introduction into the calculations are considered in detail. An explanation is suggested for the saturation effect of RI from a conductor in intense corona, together with suggestions for further investigations.

CEGB Conference on Gas Discharges and the Electricity Supply Industry, Leatherhead, 1962 (See abstract 3511 of 1963), Pages 274-81.

28. Radio Noise from High-Voltage Direct Current Systems.

Hylten-Cavallius, N.

The ignition of the valves of a HV, DC converter station generates radio noise. In the report some important aspects of this generation and of different means for its reduction are given.

CEGB Conference on Gas Discharges and the Electricity Supply Industry, Leatherhead, 1962 (See abstract 3511 of 1963), Pages 295-306.

1963

29. Etude des perturbations radioelectriques engendrees par des convertisseurs statiques a haute tension.

Clade, J.

Study of radio interference caused by HV static converters; measurements are reported, made at Echinghen converter station, at French terminal of cross channel cable, reduction of interference to Relatively negligible levels was accomplished by means parallel and series connected RC filter network in substation circuit.

Rev. Gen. de l'Electricite Volume 72, No. 6, June 1963, Pages 343-57.

FRANCE

30. Contribution to the Study of Radiophonic Disturbances Produced by MV Lines.  
Gary, G.  
While the phenomena in rigid and suspension insulators are of different origin, the mathematical expressions and the test methods are the same. Experiments give the spectral distribution of the perturbation current up to 50 Mc/s. The effect of propagation conditions at different frequencies is discussed and a simplified equation is derived. Field measurements give higher value than those taken in the laboratory and further studies of these differences are projected.
- Revue Generale de l'Electricite,  
Volume 72, No. 10,  
Pages 503-18.  
(October 1963)  
In French.
31. Contribution a l'etude des perturbations radiophoniques engendrees par les lignes a moyenne tension.  
Gary, G.  
Radio interference produced by medium voltage lines, it is shown that same expressions and same test methods can be applied in investigations of interference phenomena on rigid and suspension insulators, respectively, through origin of interference on 2 insulator types of different origin; Spectral distribution of interference current up to 50 Mc/s is derived, along with simplified expression.
- Revue Generale de Electricite,  
Volume 72, No. 10,  
October 1963,  
Pages 503-18.
- 1964
32. Attenuation Measurements on a High Voltage Overhead Line.  
Bartenstein, R.  
The calculation of HF interference on overhead lines presupposes a knowledge of the transmission characteristics of the line. During the construction of a 110 kV overhead line with 240/40 (21.7 mm diameter) asc conductor in a triangular configuration
- Conf. Int. Grands Reseaux Elect. (CIGRE) (France) 1964, Paper 419, Page 21.

## FRANCE

it was possible to measure the frequency-dependent transmission characteristics of the line in different states of construction. These measurements permitted the calculated transmission characteristics to be checked and corrected if necessary. The measurements were at first carried out with only one phase conductor in place. Subsequently the two other conductors of the three-phase system were installed and the transmission characteristics measured of the three different transmission circuits (modes) for HF interference currents which are largely independent of each other. For an earth conductivity of  $3.8 \times 10^{-4}$  v/cm and 500 kc/s an attenuation of 1.7 dB/km was obtained for the mode 3 (with earth return) and of 0.10 dB/km and 0.12 dB/km for the balanced modes 1 and 2 which are symmetrical to earth. For the single-phase line with earth return an attenuation of 0.96 dB/km was measured. Other attenuation values are compiled in a table.

33. Corona Losses, Radio Interference and Insulator Requirements for High Voltage DC Lines. Studies Regarding Insulator Interference for Frequencies Between 30-1500 Mc/s.

Conf. Int. Grands  
R. Elect. (CIGRE)  
France 1964,  
Paper 407, Page 21.

Hylten-Cavallius, N.

Systematic measurements of monopolar HV DC corona losses up to 1 mv and bipolar up to  $\pm 350$  kV are compared with calculations and reasonable agreement is found. The variations of losses with weather, conductor diameter, height and spacing is illustrated. Measurements of radio interference from the line have been carried out simultaneously with measurement of corona losses. The nominal conductor gradient appears to determine the radio interference at least for the range of practical interest.

## FRANCE

Studies have been made regarding radio interference from line insulators for frequencies between 30-1500 Mc/s. Some aspects are given on the insulation of DC lines and choice of DC insulators and the result of long-term pollution test is given.

34. Some Design Aspects of Harmonic Filters for HV DC Transmission Systems.

Iliceto, F.

With the advent of high power converters for HV DC transmission systems, little attention was paid to harmonics in electrical power networks, because in general, harmonic levels were found to be acceptably low. Installations of HV DC converters, however, are large relative to the network to which they are connected and it becomes necessary to install filters to reduce harmonic currents and voltages produced by them. The paper is divided into two parts. The first gives a discussion of harmonic penetration in a network, and methods of defining and specifying harmonic disturbance. The second gives a description of filter designs for a particular installation and their design basis.

Conf. Int. Grands  
R. Elect. (CIGRE)  
(France) 1964  
Paper 405, Page 35.

35. Considerations generales sur les perturbations radioelectriques et les possibilites de deparasitage a la source.

Fromy, E.

Radio-frequency interferences and possibilities of their elimination at source; origins of various types of interference are systematically investigated and methods and arrangements proposed for measuring influence on electric lines and line models, general considerations are presented for how to use results of study for interference suppression.

Revue generale de  
'lElectricite,  
Volume 73, No. 6,  
June 1964,  
Pages 353-64.

## FRANCE

- 35A. Progress Report of Study Committee No. 9 on Extra-High Voltage AC Transmissions. CIGRE, Paper 420, June 1964, RI Section.  
Sporn, Ph.

Poses question of limitation of radio disturbances produced by power transmission lines.

In view of present knowledge, it appears impossible to propose, under any form whatsoever, a limitation of stray fields in the vicinity of power transmission lines. At present, the only effective method (increase of conductor cross-sections) would result in such an increase in the cost of lines that their construction would become impossible. Detailed mathematical treatment of propagation of HF on overhead lines.

## GERMANY

### 1959

36. Untersuchung des hochfrequenten Spektrums periodischer Entladungen. Zeit fuer Angewandte Physik, Volume 11, No. 2, February 1959, Pages 51-7.  
Heintz, W.

Study of HF spectrum of periodic discharges. Experimental and theoretical analysis of discharge pulses, HV transmission line corona, contributing to interference in HF communication.

### 1960

37. Untersuchungen ueber Glimmentladungen an Armaturen fuer 110 kV Freileitungen. Elektrizitatzwirtschaft, Volume 59, No. 5, March 5, 1960 Pages 128-30.  
Baer, K.W.

Corona discharge on fittings of 110 kV overhead lines; tests carried out on conventionally used and recently introduced new type of fittings, in interest of radio interference suppression.

## GERMANY

### 1960

38. An Instrument for Measurement of Interference Field Strength in the Frequency Range 30 to 225 Mc/s.  
Lorenz, H.
- Nachrichtentechnik,  
Volume 10,  
Pages 23-8,  
(January 1960)  
In German.
- A general description of the FMG2 instrument developed by VEB Funkwerk, Dresden, which operates as a calibrated heterodyne receiver. A block diagram shows the arrangements of the various units. The total frequency range is covered on 8 scales and the uncertainty of the frequency indication is  $< \pm 1\%$ , while the frequency constancy is better than  $1 \times 10^{-3}$  for 60 min. after a 5 min. warm-up period, a quartz controlled oscillator being used for the second mixer stage. A detailed account is given of instrument working and calibration.

### 1961

39. Interference between Power Lines and Telecommunications Installations.  
Sajonz, J.
- Frequenz (Germany)  
Volume 15, No. 3,  
Pages 79-87,  
(March 1961) In  
German.
- A comprehensive paper, dealing, on restricted space, with risk of danger and noise disturbances, electric and magnetic induction, internal impedance of an induced line for both forms of induction, calculation of longitudinal induced voltages, allowing for screening effects and protective measures against dangerous voltages and noise.
40. Die Beeinflussung von Schwachstromanlagen durch Starkstromleitungen.  
Sajonz, J.
- Frequenz, Volume 15,  
No. 3, March 1961,  
Pages 79-87.
- Influence of low current installations by high current transmission lines, capacitive and inductive influences, due to rigid grounding of neutral point, increasing adoption of electric traction, etc.

## GERMANY

### 1962

41. High-Frequency Mains Filters for Electromagnetically Screened Rooms and High Voltage Halls.

Ortloff, M.

The increasing number of powerful transmitters and electromagnetic disturbances necessitates the introduction of totally enclosed mains filters of improved design in the mains supply of screened rooms. Commercially available mains filters have 60 dB attenuation in the frequency range from 150 Kc/s to 30 Mc/s which can be extended to 100 Db. Attenuation up to 1 Gc/s. Construction of a typical 6 kV 200 A wide-band filter is shown and several others, consisting of double or triple  $\pi$  filters are described.

Elektrotech Z. (ETZ)  
B (Germany),  
Volume 14, No. 23,  
Pages 630-3  
(November 12, 1962)  
In German.

### 1962

42. Continuous Measurements of High-Frequency Interference Level of HV Transmission-Lines and Their Statistic Evaluations.

Bartenstien, R.

Measurements carried out on 344 km, 380 kV transmission (West Germany), line; existing conception that investigations of different parameters are best to be carried out on short test line, has been confirmed.

Conference Int. des  
Grands Reseaux  
Electriques a Haute  
Tension 19th,  
May 16-26, 1962  
CR, No. 409, Page 15.

### 1963

43. Corona Pulses, RF Spectra and Their Relation to Non-Ionizing Collision Cross-Sections.

Baumann, E.

Since the voltage of the German grid system has been raised to 380 kV, corona was investigated in 400 kV test plants

CEGB Conference on  
Gas Discharges and  
the Electricity  
Supply Industry,  
Leatherhead, 1962,  
(See abstract 3511  
of 1963),  
Pages 238-49.

## GERMANY

and in laboratories. A point of great importance for the power supply is the RF interference spectrum which is caused by corona discharges on outdoor lines. The corona discharge pulses propagate along the lines and interfere with the transmissions of measurement and control signals. The RF interference currents in the conductors also cause electromagnetic disturbance field strength close to high voltage lines. The intensity and frequency range of these interference spectra should be calculated from laboratory tests or from experiments with outdoor test lines. Therefore, to permit such calculations, correct results must be used in the equations. In this paper the relation between the interference spectrum and the movements of the charge carriers in the field is shown, in the case of short lines with corona discharges. There follows a correlation between the frequency spectrum and the effective non-ionizing collision cross-section which is basically important for all further physical and technical experiments.

### 1964

44. The Predetermination of HF Interference Caused by High Voltage Lines. Von Pfaler, C.E. A mathematical article in which the relationship between the field strength close to a three-phase line and the interference current generated per unit length of conductor due to corona discharge, which can be measured on a short single-phase line is derived.
- Elektrotech Z (ETZ) A (Germany), Volume 85, No. 9, Pages 261-6 (May 1, 1964). In German.



GERMANY

1964

45. Die Vorauskrechnung der von Hochspannungsleitungen verursachten hochfrequenten Störungen.  
Pfalzer, E. von  
LfZ (Ed. A)  
Volume 85, No. 9,  
May 1, 1964,  
Pages 261-2.  
Precalculation of HF interference by hv lines, quantitative relationship is given between interference current caused by corona discharges in unit length of single phase line.
46. Possible types of Interference with Radio Direction-Finding Installations by Medium and High Voltage Power Systems.  
Fronmer, E.  
Nashrichtentech, Z. (NTZ) (Germany)  
Volume 17, No. 9,  
Pages 468-71,  
(September 1964).  
In German.  
Deals with investigations concerning the minimum separation between an existing radio direction finder and a planned medium voltage line. Interference carries in two ways: The power line can be an active source of radiation, or it can re-radiate, as a secondary source, signals sent from the transmitter and, hence, disturb the accuracy of the direction. Both effects, are considered separately; it has been found that in the case in question, the indirect effect was decisive dictating a minimum separation of approximately 500 meters.
47. Parameters of Three-Phase High Voltage Systems Related to Inductive and Conductive Coupling with Telecommunications Circuits.  
Feist, K.H.  
Elektrotech Z (ETZ) A (Germany),  
Volume 85, No. 20,  
Pages 641-6,  
(October 2, 1964).  
In German.  
Investigates the significance of the various parameters which determine voltages in telecommunications circuits induced from parallel power lines, or impressed, by conductive coupling, when the telecommunication installation approaches earthing points of high voltage systems. Discussed are zero sequence currents, particularly in networks with earthed

GERMANY

neutral, double-three-phase lines, variation of screening factors with current which can make unreliable, extrapolation of measurements made with small currents, effects in cable networks and screening by earth wires. Measurements under different conditions are explained in detail.

48. Notes on the History of Inductive Interference Between Power Lines and Telecommunication Lines. Elektrotech Z (ETZ) A (Germany), Volume 85, No. 20, Pages 625-30, (October 2, 1964). In German.  
Klewe, H.  
A brief historical survey, beginning with disturbances by the earliest railways, and dealing with electric induction, acoustic shocks, ac and dc railways, particularly if rectifiers are involved, mutual inductance between lines with earth return, measurement of noise due to harmonics, unbalance of lines and equipment, as well as with international cooperation, international and national rules and directives, and the limits for dangerous and disturbing voltages. The development of new power and telecommunication techniques leads time and again to new problems which should be resolved by cooperation between the two sides.
49. Further Development of Electrical Systems From the Point of View of Electrical Interference Technique. Elektrizitätswirtschaft (Germany), Volume 63, No. 22, Pages 769-73, (October 26, 1964). In German.  
Dennhardt, A.  
Electric systems, whether power systems of the electricity supply type, or HF systems in the field of power electronics, or telecommunications systems like Post Office Networks or broadcast reception in highly developed industrial countries, are continuously increasing in type and extent. Therefore the problems arising in electrical interference technique, in attempts to avoid collisions in spite of the growth of existing and planned systems, are becoming wider. On the basis of the expected development

## GERMANY

the resulting change in interference magnitudes, and the methods of suppression necessary to deal with them, are discussed. It is found that, with reasonableness and care, the problems will be solved in the future also.

## ITALY

### 1959

50. The use of Noise Measurements for the Determinations of the causes of Internal Ionization in High-Voltages Equipments.

Cappuccini, F.

Energia Ellettrica  
Volume 36, No. 10,  
Pages 889-98  
(October 1959).  
In Italian.

An account is given of experiments carried out to discover any correlation between noise in HV apparatus, e.g. transformers and the voltages applied; and between increases in noise level and the incidence of breakdown. The measuring instrument was superheterodyne receiver with a specification similar to the draft specification of the committee Internationale Special les Perturbations Radio Electriques (CISPR), but with a reduced BW (6 Kc/s) and more stringent requirements for image and intermediate-frequency selectivity. A schematic diagram of the test installation is given and precautions to be taken are discussed. Check of noise levels measured on 32 transformers before, during and after an insulation test show a marked increase in noise during the test and a reduction after the return to rated voltage. For transformers rated at 69 kV the noise level returned almost to normal, but the reduction was much smaller in transformers for higher voltages (115-220 kV). Similar tests on a few specimens from the bath after desiccation and impregnation showed a marked reduction of noise at all stages.

## ITALY

### 1960

51. Conductors for Highest Voltages and Related Questions.  
Paris, L.  
Deals with general economics, radio interference, corona losses and hardware.
- Riun. Association  
Eletrotech  
Italiona (Ancona  
1960) Fasc. II,  
Paper 141, Page 6,  
(published 1960-61)  
In Italian.

### 1962

52. Psophometric Measurements on High-Tension Power Lines.  
Curcuruto, A.  
Noise measurements have been carried out on 60-120 and 150 kV lines to provide data required in the investigation of interference induced in the telephone network.
- RC (63) Riun. Assoc.  
elletrotecnica  
italiana Fasc. III,  
Paper 122, Page 3  
(Ischia, 1962).
53. Measurement of Radio Interference and Ionization on High Voltage Equipment.  
Brasca, E.  
Corona discharges and ionization effects in solid or liquid dielectrics are considered; (a) with respect to the radio interference they produce; and (b) as an indication of the physical state of the insulating material. Methods are described of measuring and specifying the level of the effects.
- RC (63) Riun Assoc.  
Electrotecnica  
Italia Fasc. III,  
Paper 129, Page 5  
(Ischia 1962).

### 1963

54. L'effettio Corona in Tensione Continua--  
Analisa Oscillografica.  
DeBernochi, C.  
DC corona effect; oscillographic analysis; results obtained with model of cylindrical field presented; intermittent nature of discharge is confirmed, characteristics features of discharge which depend on polarity of live conductor are determined.
- Energia Elettrica  
Volume 40, No. 9,  
September 1963,  
Pages 714-20.

## ITALY

### 1964

- 54A. Some Considerations on Possible Criteria to be Adopted for Corona Measurements on Insulators Strings. Sforzini, M. CIGRESC, No. 5, Insulators Meeting at Bellagio, May 1965, Doc. 65-7.

The considerations that are exposed in this report are based on the experience acquired in a series of radio-noise tests, which were made both in the field on 420, 245 and 145 kV lines and in the laboratory on single insulators and insulator strings of the types more commonly used in the above lines.

The results of the tests performed, and also some of the criteria which are briefly discussed here, are more extensively described in a few reports which were presented at the Palermo Meeting of the Italian Electrical Association (AEI) September 1964, <sup>1</sup>, 2 and 3.

- 54B. Investigation to determine conditions of RI at different times of the 24-hour day, using data provided by long term measurements on the 380 kV Bovisio Test Line. CISPR-WG-3, (Sforzini-Italy) April 20, 1965.

Sforzini, M.

Investigations revealed no significance differences in the distributions of RI for day and night (1 am to 6 am).

Likewise with the factors influencing corona (voltage, rain, relative humidity, atmosphere pressure etc.).

Fog at night would necessitate that RI data at this time be considered when evaluating.

- 54C. Results of RIV Measurements made in Laboratory on insulators and insulator strings for the purpose of comparing the two test circuits proposed by CISPR. CISPR-WG-3, (Sforzini-Italy) April 20, 1965.

Sforzini, M.

### ITALY

- 54D. Formulas for Predetermination of  
Radio Interference from Electric  
Power Lines.

ENEL Direzione  
Direzione Studi e  
Ricerche, 1964.

Sforzini, M.

Detailed investigation and comparison  
of methods and formulas used by many  
different countries for the predetermination  
of RI from electric power lines.

### JAPAN

#### 1959

55. Corona Noise Tests on Extra-High  
Voltage Transmission Lines with  
Enclosed Type Concentric Cylinders.

Electrotechnical  
Journal of Japan,  
Volume 4, No. 4,  
December 1958,  
Pages 127-131.

Kino, J.

Apparatus for corona noise measurement  
on 275 kV lines, by use of which rate  
of rainfall can be controlled from 0.4  
to 1.0 mm/min. relative humidity from  
20% to 90% and atmosphere pressure from  
400 to 1000 mm Hg; data obtained on surface  
gradient, atmospheric pressure, humidity and  
rainfall characteristics of single and double  
conductors and of influence of surface  
conditions.

56. Study on Shape of Current Pulses of  
Corona at Point of Piece or Drop of  
Insulating or Semi-Conducting Materials  
on Electrode.

Inst. of Elec. Engr.  
Japan - Journal  
Volume 79, No. 854,  
November 1959,  
Pages 1429-36.

Enjoji, H.

Laboratory studies of coronas at end  
of glass capillary, in gap filled with  
water, aqueous solution of KCl, or  
organic liquids, in order to deduce from  
pulse shape fundamental processes of radio  
interference of electric transmission lines  
in rain, roles of air moisture and of

## JAPAN

### 1959

solubility of liquid materials in water, in extending pulse tail. In Japanese with English summary.

### 1960

57. Study on Transition from Pulsative to Pulseless Negative Corona in Air. Enjoji, H.  
Study of negative corona without Trichel pulses in air, on electric power transmission lines, in interest of reducing Radio Interference; from experimental results which are given, it is concluded that distribution of negative ion space charge may be decisive in whether negative corona is pulsative or pulseless. (In Japanese with English summary).  
Inst. Elect. Engr. Japan - Journal Volume 80, No. 859, April 1960 Pages 463-71.
58. Experimental results of Radio Transmission on Extra High Voltage Transmission Line as Protective Measure Against Corona Noise. Akao, Y.  
Test results of 275 kV line of new protection system developed since 1956, which is particularly effective in case of weak radio signals. New methods make use of transmitting radio programs over interferring power line from radio transmitter through proper coupling apparatus similar to that of power line carrier systems. Power line playing role of antenna. (In Japanese with English summary).  
Inst. Elec. Engrs. Japan - Journal Volume 80, No. 859, April 1960, Pages 480-7.
59. EHV Corona Noise in Japan Yamada, T.  
The results of Japanese studies and tests on radio interference caused by corona are described. Field tests were made on 275 kV transmissions lines, and the superiority of a double conductor  
Conf. Int. Grands Reseaux Elect. (CIGRE) (France) 1960 Paper 402, Page 28.

## JAPAN

configuration verified. The introduction of 400 kV lines is anticipated, and basic design studies were made using EHV concentric cylinders and test lines. A method of estimating corona noise levels is established by combining the results of field tests and of the basic studies. Some results in the prevention of radio disturbances were achieved; factors studied were the transference of noise at the intersection of transmission and distribution lines, carrier transmissions through lines at 275 kV and the development of a filtering circuit using parallel auxiliary conductors.

### 1961

60. Coupling between two intersecting lines.  
Kageyama, Y.  
Radio interference in case power transmission line crosses distribution line, and corona noise current flowing in transmission line induces noise current in distribution line; paper considers both electrostatic coupling and magnetic coupling, crossing distribution line, for corona noise and formulates theory of approximation applicable to all angles of crossing. (Experiments in Japanese with English summary).  
Inst. Elec. Engr.  
Japan Journal,  
Volume 81, No. 874,  
July 1961,  
Pages 1109-13.
61. New Instrument for Searching Radio Noise Sources by Evaluating Noise Power.  
Amemiya, Y.  
Methods are proposed to detect noise sources on trolley wires in ac track section by means of portable radio receiver and radio direction finding apparatus; with this instrument one can locate noise sources and obtain their magnitude.  
Tokyo Ry Tech.  
Research Inst.-  
Quarterly Report  
Volume 2, No. 1,  
March 1961,  
Pages 10-15.



## JAPAN

62. Corona Pulses from Water Drop on Cylindrical Conductor Surface.  
Sato, Y.  
Experiments conducted to explain mechanism of Radio Interference from HV transmission lines in rainy weather. In Japanese with English summary.  
Inst. Elect. Engrs. Japan Journal, Volume 81, No. 877, October 1961, Pages 1606-15.
63. Experimental results of Power Line Radio Systems.  
Akao, Y.  
New method for protection against radio interference from corona of extra HV lines. Method is especially effective in areas of weak signal intensity.  
Electrotechnical Journal of Japan Volume 6, No. 3-4, 1961, Pages 115-19.
- 1962
64. Development of New Wave Trap by Parallel Sub-Conductors.  
Sawada, Y.  
Wave trap, developed to stop propagation of HF radio interference waves and carrier current in medium short-waveband along electric power transmission or distribution line, is based on stretching at least, one subconductor about  $1/4$  wavelength of HF wave to be trapped at certain distances along main transmission line, and short circuiting one end of subconductor and transmission line. In Japanese with English summary.  
Inst. Elect. Engrs. Japan Journal Volume 82, No. 885, June 1962, Pages 955-64.
65. On Distribution of Signal Field Strength in Power Line Radio System.  
Akao, Y.  
Discussion of Power Line Radio System, as method for protection of radio reception against corona noise generated from HV power lines, it is shown  
Inst. Elect. Engrs. Japan Journal Volume 82, No. 833, April 1962, Pages 544-53.

## JAPAN

theoretically that signal field distribution can be altered significantly by assuming existence of local ground return mode; experimental verification. In Japanese with English summary.

66. Interference Waves Produced by Pole Structure on Distribution Line.  
Takasu, N.  
Investigation to show that systematic repeated pulses produced at every half cycle of AC and due to repeated discharge between corrosion metal contacts of distribution line supporter, are source of RF and VHF interference, it is proposed that metal contacts, where they are used must be shorted by bond to prevent repeated pulse interference wave. In Japanese with English summary.  
Inst. Elect. Engrs. Japan Journal  
Volume 82, No. 891,  
December 1962,  
Pages 1928-37.
67. Statistical Study of Radio Noise of the 275 kV Tokyo Eastern Line.  
Sawada, Y.  
Statistical measurements of radio noise beneath a 275 kV line are described and the results given. The results show the effects of conductor aging, heavy rainfall and prolonged dry weather.  
CEGB Conference on Gas Discharges and the Electricity Supply Industry, Leatherhead, 1962, (See abstract 3511 of 1963), Pages 289-94.
- 1963
68. An analogue Device for Computing the Voltage Magnetically Induced in a Telecommunication Line by a Power Line.  
Yamaguti, T.  
The computing device consists mainly of an automatic mechanism for measuring the separation distance between a power line and a telecommunication line by the aid of an automatic curve follower, a function generator which transforms the separation distance into the mutual  
Bulletin of the Electrotechnical Lab. (Japan)  
Volume 27, No. 8586-94, (July 1963) In Japanese.

## JAPAN

impedance, an electro-magnetical integrator and an output table. The main feature of this device is that the vertical distance to the power line is always measurable by the movement of a turning arm inside the mechanism for measuring the separation distance. The computing speed of this device is about 10 km/min. and the overall accuracy is about 1% which is considered to be sufficient for estimating the magnetic induced voltage.

69. Analysis of Repeated Pulse Disturbances Produced by Transmission and Distribution Lines.

Takasu, N.

Electric field intensity of disturbances from many sources of repeated pulses are discussed, considering their transmission and prevention on transmission lines, number of repeated pulses and relations between pulse intervals and harmonic frequency distributions were clearly determined, making it certain that they affect television frequency bands; repeated pulses are shown to be more responsible for disturbances, than corona or cracked insulators.

Elect. Eng. in Japan (English Translation) of Denki Gokkai Zasshi, Volume 83, No. 3, March 1963, Pages 63-73.

### 1964

70. Experimental Investigation of Corona on the 800 kV Tanashi Test Transmission Line.

Yamada, T.

The increasing power demand in Japan of late years has made necessary the development of a new transmission system operating on a voltage of 400 kV or more. The 800 kV Tanashi Test Transmission line was recently constructed to study the corona effect on the extra high voltage transmission lines at 400-800 kV and corona measurements on quadruple 240 mm<sup>2</sup> AC SR were carried out from the beginning

Conf. Int. Grands Res. Elect. (CIGRE) France 1964, Paper 404, Page 15.

### JAPAN

of 1963 to June 1964. This paper reports the outline of the test line and the results with radio interference obtained by this experiment. As a result, it is shown that the radio interference levels on the 400 kV class transmission line with quadruple 240 mm<sup>2</sup> AC SR will be much the same as those on the existing 275 kV transmission lines.

### MEXICO

1964

71. Electric Conductors Convenient Size. Borelli, F.B. Conf. Int. Gr. Res. Elect. (CIGRE) (France) 1964. Paper 227, Page 8.
- The factors that affect the selection of the most convenient outside radius especially for bundle conductors of the high tension lines, are evaluated in a graphical and simple form. A practical application to the 380 kV transmission line now under construction, from Mexico City to Infiernillo Station is considered.

### RUSSIA

1959

72. Highly Sensitive Spectral Analysis of Low Frequency Electrical Noise. Malakhov, A.M. Instruments and Experimental Techniques (English trans. of Pribery; Tekhnika Ekrpenimenter) No. 1 January-February 1958, Pages 86-89.
- Apparatus for measuring spectral density of low frequency electrical noise in range of 1 to 300 cps e.g. in electron tubes, semiconductor etc. analyzer works on heterodyne principle with passband of 1 cps sensitivity of  $10^{-16}$  v<sup>2</sup>/cps and time constant of 20 secs.
73. No Reference.

RUSSIA

1960

74. Obrazovanie i struktura pometkh v. vozdukhnykh elekbricheskikh setyakh 0.4-35 kV.  
Smirnov, B.V.  
Formation and structure of noise in overhead electric networks at 0.5-35 kV; principal ranges of noise in range 0.05 to 155 kc/s are showed to be generators and transformers with their non-linear vs characteristics and insulators, which form partial discharge impulses, structure and magnitude of noise from these sources.  
Elektrosryaz, Volume 14, July 1960, Pages 66-74  
See also English translation in Telecommunication No. 7, 1960, Pages 813-25.
75. The Input Impedance of Broadcast-Band Noise Meters.  
Furmanov, I.M.  
Relations are derived from which the input impedance of a standard Soviet interference meter (0.15 to 25 Mc/s) is calculated.  
Radiotekhnika, Volume 15, No. 6, Pages 70-3 (June 1960)  
This impedance is small enough to effect readings when used with a standard noise measuring network for connecting to the terminals of industrial noise sources. To overcome the difficulty, an input circuit for the noise meter is proposed which includes a matched attenuator and whose impedance does not vary more than 10% from 150Ω.
76. Investigation of Interference from Corona on Transmission Lines.  
Kafieva, K. Ya.  
The levels of radio and HF interference by corona on lines without grouped conductors are permissible unless gradients exceed 26 kv/cm pk.  
Elektroizhestvo (USSR) 1960, No. 12, Pages 27-33 (Dec.).  
Conductors of planned 330 kV lines should have 33 mm as minimum diameter. If

## RUSSIA

gradient exceeds 26 kV/cm on transition to 330 kV, communication channels must be fitted with powerful output amplifiers and radio receivers in the neighborhood operated without outdoor aerials. The interference levels drops rapidly with frequency and distance from the line. In some areas, permissible gradients may be 28 kV/cm pk.

77. Analysis of Noise in a 0.4/6 kV Power Network.

Venchkovskii, L.B.

Results of the study of the noise in a 0.4/6 kV oilfield power network at 150 c/s to 100 kc/s are given.

Experimental data is analyzed statistically and approximate formula for the functions of the pulse-noise magnitude distribution found. (English translation in Automat. remote control (USA).

Automat; Telemekh (USSR), Volume 21, No. 8, Pages 1181-7 August 1960. In Russian.

- 77A. Corona Investigation on Extra-High Voltage Overhead Lines.

Burgsdorf, V.V.

The report presents an account of experimental investigations on corona-losses, undertaken on test and operating lines and a description of applied measuring circuits, and suggests generalized characteristics for corona loss measurements under different weather conditions. Besides, it shows characteristic values of 330-500 kV line losses and the results of radio-noise and interference with HF communication channel measurements.

CIGRE, Paper 413, June 1960.

## RUSSIA

### 1962

78. A Method for Computing the High-Frequency Parameters of Overhead Electric-Power Transmission Lines.

Orlov, V.N.

A method of calculating the high-frequency parameters of overhead electric-power transmission lines is examined. The basic portion of the discussion is concerned with allowance for ground losses, which have a substantial influence upon the value of line attenuation. It is proposed to use, for this purpose, charts and approximate expressions obtained by the authors for various Carson functions.

Telecommunication and Radio Engineering, Part 1, No. 7, July 1962, Pages 60-70 (English translation of Russian Elektrosvyoz and Radiotekhnika).

### 1963

79. Interference from Partial Discharges on the Insulators of 0.4-35 kV Electric Lines.

Sarapkin, V.V.

The mechanism of formation of a system of pulses from partial discharges on the insulators of a three-phase line is described. The structure of the interference spectrum is considered to depend on the following: the number of pulses in a series, the variation of amplitude, and the duration and instant of appearance of the pulses. The results of experimental research on interference in electric lines are quoted. Methods of calculating, the interference in the development of apparatus intended for operation through the conductors of 0.4-35 kV lines are developed.

Elektrosvyaz (USSR) 1963, No. 4, In Russian English translation in Telecomm. Radio Eng. pt. (USA), 1963, No. 4, Pages 64-73 (April 1963).

RUSSIA

80. Tracing the Sources of Radio and Telegraphic Interference from 110 kV lines by means of a fault detector.

Karamzin, A.P.

Describes the manner in which an interference locator type 1P-12 and a fault detector type D8 were used to trace sources of interference arising from 110 kV, transmission lines in the Sverdorsk power system. The guilty line was found by successively cutting out all the lines passing through the affected area. It proved to be a seven mile stretch of two-circuit line carried on metallic pylons. Four offending sections were localized in two areas by means of a fault detector, in one case by the interference locator; and the final case by visual observation at night. The fault detector enabled fault to be located to be within 3 to 4 pylons, it is smaller, cheaper and more convenient to use than the 1.p.12 instrument, and gives readings easily identifiable above the background of corona. The sources proved to be an assortment of faulty insulators, and bad connections in the shield wires.

Elektricheskie  
Stantsii (USSR)  
1963, No. 3,  
Pages 82-4 (March)  
In Russian.

81. Some Special Features of Corona on High Voltage D.C. Transmission Lines.

Popkov, V.I.

With unipolar dc corona, both increase in the electrode spacing and the use of negative polarity on the conductor decrease corona current and power loss; with bipolar corona, the higher ion densities cause higher corona current and power loss. Since the losses from two unipolar conductors are lower from those of bipolar conductors, it is suggested that DC lines be built on the independent towers spaced widely apart. It is shown that the earthwire in a unipolar system increases the potential gradient at the line conductor, causing

CEGB Conf. on Gas  
Discharges and the  
Electricity Supply  
Industry, Leather-  
head, 1963, (See  
abstract 3511 of  
1963) Pages 225-37.



## RUSSIA

higher corona power loss. Under certain conditions, corona can occur on the earthwire, and the resulting bipolar corona causes still higher loss. There is no correlation between corona loss and the radio noise from conductors. Greater interference occurs when the conductor is positive, and, although in rain the noise commences at a lower voltage than in dry conditions, the noise with higher voltages is lower in rain. Surface coatings are only effective in reducing interference from conductors having negative polarity. Screening wires, which generate super corona, are effective in suppressing streamers with positive polarity, and this reduces the radio interference.

### 1964

82. The 750 kV Experimental-Commercial Transmissions Line Konakovo-Moscow. Akopyan, A.A. Conf. Int. Gr. Res. Elect. (CIGRE) (France) 1964 Paper 413, Page 16.
- The growth of the electric power industry in USSR makes it necessary to further increase the voltage for AC transmission systems. By the end of the next five year plan (1966-1970) it is planned to erect several powerful 750 kV transmission systems. The experimental-commercial 750 kV transmission line Konakovo-Moscow is to be erected for gaining experience and conducting research on transmission systems in this class. The report discusses several operations connected with the 750 kV transmission line.
83. Metodika rascheta radiopomekh of korony na provodakh linii elektroperedachi. Perelman, L.S. Elektrichestvo, No. 10, October 1964, Pages 57-62.
- Methods of calculating radio interference from corona of conductors of power transmission lines, analytical method is described, which

## RUSSIA

is claimed to overcome shortcomings of method proposed by R.E. Adams, that does not account for fact that vertical component of electric field in relation to distance to ground decreases at slower rate than some component of quasi-static field; hence calculation of radio interference should take into account wave characteristics of field, calculation of corona interference from 500 to 750 kV lines.

- 83A. The Corona Effect and Selections of Conductors for 500 kV Power Transmission Lines.

Burgsdorf, V.V.

Symposium on Long-Distance electro-transmission, 1964, Pages 106-117.

This paper discusses corona loss and radio interference (RI). It gives RI data including statistical data, obtained in several types of weather and for several conductor surface conditions. It is recommended that statistical methods be used to determine the RI level of a line. It is stated that with a three conductor bundle of 1.2 inch dia. conductors, the interference is below their design limit for practically all of the time. No correlation between their meters and CISPR or U.S. RI meters is given. It is stated that aging of lines reduces interference by 5 to 8 times from that obtained with new conductors. Instrumentation is referred to which records without paper chart every 1/2 to 10 minutes and which includes means for simultaneous statistical processing.

## SWEDEN

1959

84. Wave Propagation Along Three-Phase Power Lines and Telephone Lines with Power Induction.

Pettersson, G.A.

Ericsson Techniques (Sweden) Volume 15, No. 2, Pages 221-48, 1959.

## SWEDEN

Expressions are derived for the currents and voltages in a three-phase power line without earth wires. It is shown that a line that is not balanced by using transpositions is characterized by five impedances and three wave propagation states. The effectively transposed line has two characteristic impedances and two, wave propagation states. The formula presented has proved to be suitable for practical analysis, of the characteristics of three-phase lines. In addition, expressions are given for the influence of the three-phase line on a telephone line.

### 1960

- 84A. DC Insulators, A Comparison with AC.  
Witt, H.

CIGRE Paper 403,  
June 1960.

Various aspects of DC insulation as compared with AC have been studied theoretically and experimentally, with particular regard to the possibility of converting the vast experience gained from AC systems into use for DC systems.

As a result, an attempt has been made to give reasonably definite recommendations for the insulation of HV DC lines to be used in the estimation of transmission costs.

These recommendations are considerably, influenced by the favorable fact that DC systems can be so arranged and controlled that switching surges and other internal overvoltages are negligible.

### 1962

85. Radiostorningar from Stodisdatorer.  
Larsson, O.  
Radio interference from pin type

Elteknik, Volume 5,  
No. 3, March 1962,  
Pages 45-7.

## SWEDEN

type insulators, study on Swedish 30 kV lines using wood poles, interference level can be reduced considerably by using special types of insulators having semiconductor glaze, best results were obtained with clamp-top insulators.

### 1964

86. Corona Loss and Radio Interference Measurements at High Voltage AC on Test Lines in Sweden.

Knudsen, N.

Conf. Int. Gr. Res.  
Elect. (CIGRE)  
France 1964,  
Paper 411, Page 17.

On a test plant erected by the Swedish State Power Board in connection with the Chalmers University of Technology in Gothenburg comprehensive corona tests have been carried out during the last years. Beside the general intention to broaden the theoretical and practical knowledge about the corona phenomenon there has been a special purpose namely to compare the behavior of double and triple conductors of the types used in Sweden which contain cables with a diameter of 3.2 cm and a spacing of 45 cm. The results of the experiment indicate that by the use of triple conductors instead of double conductors the yearly losses, apart from ice losses, are reduced from about 1.4 kw/km to about 0.4 kw/km and the radio interference level is reduced by about 8 dB in fair weather and probably somewhat more in bad weather. Expressed in another way the triple conductors has given approximately the same losses and radio disturbances at 460 kV as the double conductor at 400 kV. Variations between 40% and 95% in the humidity in the air did not seem to affect the losses but a slight decrease in radio interference with increasing humidity was observed. Bad weather has given increasing losses in the following order: fog, dry snow, rain, wet snow, hoar frost. A method for calculating fair weather losses is proposed and future work is outlined.

## SWITZERLAND

1963

87. Electrical Requirements for EHV Lines.  
Berger, K.  
Problems arising in normal service include, switching overvoltages, corona losses and radio interference. These are dealt with by suitable design of insulators and conductors, largely by use of bundle conductors. Modern theory of lightning protection is reviewed. The high load and fault currents in large systems necessitate particular attention to joints, tower earthing and earth wires, overhead or buried, in order to minimize interference with communication systems.  
Bull. Assoc. Suisse des Elec.  
(Switzerland),  
Volume 54, No. 18,  
Pages 749-55  
(7th September 1963)  
In German.
88. Grundlagen und Organization des Radio-und Ferncehentstoomy, in der Schweiz.  
Mesiter, E.  
Fundamentals and organization of radio and television interference in Switzerland, summary of regulation and of methods used for disseminating information to public; service for eliminating interference, its financing, equipment, and procedure upon receiving complaints from subscriber. In German and French.  
Bull Technique  
(Technische Mitteilungen),  
Volume 41, No. 9,  
1963, Pages 309-20.
89. Recherchas statistiques et experimentale, em le domeine des lignes electriques.  
Poltier, L.  
Statistical and experimental study of electric lines, results of experiments on Swiss experimental lines are summarized concerning icing and wind effects on lattice steel towers and 220 kV conductors; statistics are presented on line failures in 14 countries.  
Assn. luisse des Electriques-Bul.,  
Volume 54, No. 20,  
October 5, 1963,  
Pages 831-6.

SWITZERLAND

90. Der Radiostoersuchwagen der Radio-  
and Fernseh-Dienste.

Meister, E.

(Technische  
Mitteilungen PTT),  
Volume 41, No. 5,  
1963, Pages 184-96.

Mobile interference-locator for radio  
and TV services; details of electric  
equipment and its installation in Simca  
station wagon of 1000 kg load capacity;  
apparatus can cover range of 40 mc/s to  
about 1 GC; optical goniometer (Plirch of  
Viernheim, West Germany); directive,  
roof mounted, wideband dipole antenna, elect-  
rically rotatable at 0 to 120 rpm, and  
including telescope elements; panoramic  
circular oscilloscope, with its beam  
synchronized with antenna rotation, using  
400 c/s generators; 220 V AC is converted  
from 24 V DC measurement supply, wobulator-  
oscilloscope set scans 1-, 7-, or 9 Mc/s  
bandwidth as panorama.

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APPENDIX VII PART (2)

RADIO INTERFERENCE - HIGH VOLTAGE POWER LINES

AMERICAN LITERATURE 1960 TO 1966

The literature is in abstract form and arranged alphabetically by means of the authors name.

Pages 45 and 46 have an author index arranged alphabetically and on pages 47, 48 and 49 there is a subject index.

NOVEMBER 1966

# RADIO INTERFERENCE-HIGH VOLTAGE POWER LINES

## AMERICAN LITERATURE 1960 TO 1966

### AUTHOR INDEX

AUTHOR	REF. NO.	AUTHOR	REF. NO.	AUTHOR	REF. NO.
AIEE Working Gp.	1	Gabriellea, A.	15	Mather, R.J.	28, 29
Abboushi, A.K.	2	Graham, R.E.	16		
Adams, G.E.	3			Maxwell, E.L.	30
		Griscow, S.B.	17		
Arismunandar, A.	4			Maziotti, I.	31
Armstrong, H.R.	4A	Harmon, R.W.	18		
Ball, C.O.	5			Morris, R.M.	32
Bailey, B.M.	5A	Helstrom, C.W.	19		
Barthold, L.O.	6	Hoglund, N.A.	19A	Nigol, O.	33, 34
		Hylten-Cavallius, N.	20	NEMA	34A
Bond, C.R.	7			Newell, H.H.	34B
Bouiet, L.	8, 8A	IEEE	21	Pakala, W.E.	35, 35A, 35B, 35C
				(1966)	
Clark, D.B.	9, 10, 10A	Hinchman Corp.	22	Pearson, G.A.	36
Denholm, A.G.	11, 12	Jacobs, E.	23	Perz, M.C.	37
		Jordan, E.C.	23A		
Deitz, J.	12A	La Forrest, J.J.	24, 25, 25A	Rakoshdas, B.	38
DDC	13			Rawls, J.A.	38A
Egli, J.J.	13A (1957)	Leslie, J.R.	26	Reichman, J.	39, 40, 41, 42
Epstein, M.	14	Lorch, J.	27		
				Robertson, L.M.	43, 44, 45, 46, 47



RADIO INTERFERENCE-HIGH VOLTAGE POWER LINES

AMERICAN LITERATURE 1960 TO 1966

AUTHOR INDEX

AUTHOR	REF.NO.	AUTHOR	REF.NO.	AUTHOR	REF.NO.
Sandell, D.H.	48	Wagner, C.F.	59		
		Wilson, P.B.	60		
Schroeder, T.W.	49				
Skomal, E.N.	49B, 49C, 49A				
Stone, L.N.	50				
Taylor, E.R.	51				
Taylor, F.L.	52				
Tetley, W.H.	53				
Timascheff, A.S.	54, 55,56, 57				
Vogelman, J.H.	58				

# RADIO INTERFERENCE-HIGH VOLTAGE POWER LINES

AMERICAN LITERATURE 1960 TO 1966

## SUBJECT INDEX

THEORY AND LABORATORY MEASUREMENTS	INSTRUMENTATION AND MEASUREMENT	A.C. LINES	D.C. LINES	LINE ANALYSIS AND COMPONENTS
(a) <u>Laboratory RI Measurements</u> 12, 18, 19, 20, 23, 34A, 4A	(a) <u>Recording Instruments</u> 21, 26, 27, 34, 41, 34A, 35A	(a) <u>Corona &amp; RI</u> 25, 24, 26, 33, 19, 21, 22, 34, 1, 6, 8, 7, 12, 16, 29, 35A, 35B, 49, 50, 51, 55, 34B, 36, 37, 40, 41, 42, 39, 45, 44, 35C, 25A, 38A, 8A	(a) <u>AC/DC Comparisons</u> 38, 20, 21	(a) <u>Voltage Gradient</u> 51, 21, 35, 38, 39, 42, 54, 57, 10A, 35C.
(b) <u>Methods of Calculating RI</u> 3, 4, 2, 6, 19, 58, 53, 50, 21, 23, 37, 45, 49B, 13A, 35C, 8A	(b) <u>Tolerable Levels</u> 52		(b) <u>Converter Stations</u>	(b) <u>Conductor Diameter</u> 15, 16, 38, 21, 28, 35, 40, 42, 47, 51, 57, 35C
(c) <u>Theory of RI From Lines</u> 19, 21, 3, 4, 25, 45, 59, 35C	(c) <u>Sampling Methods</u> 35A, 34A, 58, 6, 5, 24, 26, 27, 51, 28, 29, 33, 35, 47, 60		(c) <u>Corona &amp; RI</u> 38, 1, 20, 32	
(d) <u>Measurement of Line Characteristics</u> 3, 4, 6, 15, 19, 21, 34, 37, 45, 59, 34A	(d) <u>Instrument Error</u> 21, 23, 27, 41	(b) <u>Short/Long Line</u> 7, 19, 24, 37	(d) <u>HVDC Cable</u>	(c) <u>Line Configuration</u> 51, 54, 49, 48, 6, 57, 33, 15, 16, 18, 21, 22, 32, 39, 40, 42, 43, 46, 35, 35C, 38A
(e) <u>Repeated Pulses on Lines</u> 12, 36, 38	(e) <u>Automated Measurements</u> 27, 28, 29, 42, 47, 51	(c) <u>RI Statistics</u> 58, 51, 29, 19, 24, 28, 49A	(e) <u>Harmonic Filter for HV DC System</u>	(d) <u>Insulator Hardware RI</u> 26, 11, 18, 20, 24, 35, 38, 39, 43, 46, 21, 4A, 38A, 19A.
		(d) <u>Statistics on Line Failure</u> 4A	(f) <u>Statistics</u> 5A	
		(e) <u>Complaints</u>		
		(f) <u>Conductor Aging</u> 25, 43, 44		

# RADIO INTERFERENCE-HIGH VOLTAGE POWER LINES

## AMERICAN LITERATURE 1960 TO 1966

### SUBJECT INDEX

THEORY AND LABORATORY MEASUREMENTS	INSTRUMENTATION AND MEASUREMENT	A.C. LINES	D.C. LINES	LINE ANALYSIS AND COMPONENTS
(f) <u>Man Made</u> <u>Noise</u> 49B, 49C, 12A, 49A	(f) <u>RI Surveying</u> 21, 28, 29, 35, 41, 42, 47, 35A, 49B	(g) <u>Coupling</u>		(e) <u>Contamination</u> 42, 20, 21, 24, 25, 35, 43, 44, 34B
(g) <u>Wave Prop- agation</u> <u>Over</u> <u>Irregular</u> <u>Terrain</u> 13A, 49A	(g) <u>Instrument</u> <u>Comparisons</u> 21, 27, 34, 51	(h) <u>Radio and</u> <u>Television</u> <u>Interference</u> 49B, 19A		(f) <u>Foul Weather</u> <u>Effects</u> 8, 16, 21, 24, 26, 32, 35, 43, 44, 51, 55, 4A, 8A
	(h) <u>Locating Source</u> <u>of RI</u> 21, 35	(i) <u>Line</u> <u>Intersections</u> 52		(g) <u>Transformers</u> <u>Etc.</u> 35
(h) <u>Electro- Magnetic</u> <u>Waves and</u> <u>Radiating</u> <u>Systems</u> 23A	(i) <u>Spectral Analyzer</u> <u>of Low Frequency</u> <u>Noise</u> 14, 30	(j) <u>Transmission</u> <u>of Radio Program</u> <u>Over Power Lines</u>		(h) <u>Noise</u> <u>Generators</u> 25, 35, 41, 34B, 49B
		(k) <u>Probability of</u> <u>Interference</u>		(i) <u>Corrosion</u> 35, 43
		(l) <u>Reduction,</u> <u>Prevention and</u> <u>Suppression of</u> <u>RI</u> 22, 5, 9, 10, 13, 17, 31, 35, 60, 35B, 10A		(j) <u>Prolonged Dry</u> <u>Weather</u> 24, 26, 32, 35, 39, 51, 34B
		(m) <u>Medium Voltage Lines</u> 35, 52, 4A		

RADIO INTERFERENCE-HIGH VOLTAGE POWER LINES

AMERICAN LITERATURE 1960 TO 1966

SUBJECT INDEX

THEORY AND LABORATORY MEASUREMENTS	INSTRUMENTATION AND MEASUREMENT	A.C. LINES	D.C. LINES	LINE ANALYSIS AND COMPONENTS
				(k) <u>Humidity</u> <u>Effect on RI</u> 24, 35
				(l) <u>Siting of</u> <u>Radio</u> <u>Direction</u> <u>Finder With</u> <u>Respect to</u> <u>Medium Volt-</u> <u>age Line</u>
				(m) <u>Altitude</u> <u>Effect</u> 45, 46
				(n) <u>Bus and</u> <u>Station</u> <u>Equipment</u> 25A

uncorrected capacitive matrices. This paper derives correction factors for the latter matrices, thereby bridging the gap which has existed for some three decades since the last correction terms for inductances were introduced. Although the correction factors proved to be small for switching surge frequencies and some power line carrier frequencies and typical earth constants, they are not negligible for radio frequency applications.

5. Simulation Tests on Interference Rejection Antenna System  
Ball, C.O.

Method is described for receiving signal from known or selected direction while rejecting interference arriving from single direction, interference rejection is affected by using three identical antenna elements in conjunction with computer.

IRE Int. Convention  
Rec. Volume 8, Pt. 8  
(Aeronautical and  
Navigational  
Electronics, etc.),  
1960, Pages 3-9.
6. Radio Frequency Propagation and Attenuation on the American Electric Power Dequene-Olive 345 kV Line.  
Barthold, L.O.

Attenuation constants for each of six characteristics modes of radio noise energy propagation along double circuit vertical configuration line; comparison of calculated and measured electromagnetic field factors for each of these modes.

Paper 60-192, AIEE,  
Transactions on  
Power Apparatus and  
Systems, Part III,  
Volume 79, June 1960  
Pages 303-309.
7. Experimental Comparisons of Radio Influence Fields from Short and Long Transmission Lines.  
Bonds, C.R.

Tests on section of 70-mile-345 kV transmission line to show that for RI generation long line RI level can be obtained from short test line data; tests with single RI source on line are also described.

Paper 62-1406, AIEE,  
Transactions on  
Power Apparatus and  
Systems, Part III,  
Volume 82, April 1963,  
Pages 175-185.

8. AC Corona in Foul Weather I. Above Freezing Point.  
Boulet, L.  
After a brief survey of water appearance in the close-to-ground layer of the atmosphere, behavior of water drops in the electric field is analyzed and the mechanism of streamer formation shown. Water influence, causing corona increase, has two components: (1) discharges between conductor and passing drops and (2) streamers produced by water presence on the conductor. Results of some attempts to limit streamer formation when water is present on the conductor are reported.

Paper 64-51, IEEE, Transactions on Power Apparatus and Systems. Volume 83, May 1964, Pages 508-520.
9. Naval Civil Engineering Lab Port Heuneme California.  
Clark, Don B., Hitchcock, Robert D.  
Contiguous wrapping of transmission line conductors with High-mu tape for large radio-interference attenuation.

AD-235 873 5/1 7/1  
March 60, NCEO  
TRO620TRO620 F006  
09 201.
10. Evaluation of the Interference-Suppressing Power Conductor.  
Clark, D. B., Brooks, J. L.  
Field evaluation was made of a 4-mile installation of 13.2 kV, 3-phase, special interference attenuating power line. The special line with large magnitudes of interference at its beginning, is shown to attenuate effectively over the broad frequency spectrum to bring the noise level of the line down to the level of the natural ambient in about half of its length. Impedance measurements of the power line as a transmission line showed it to be independent of line terminations, and that considerable attenuation was present. Field intensity measurements showed that the intensity decreased rapidly in greater than inverse square with distance, indicating a field propagated along the line, with no measurable

AD68 730 Div. 7/1  
8/1 25/1 - Naval Civil Engineering Lab Port Heuneme California, December 61.

radiation away from the line. The effect of the high-permeability tape thickness on attenuation is considered theoretically and experimentally, and it shows that attenuation is proportional to the tape thickness until the thickness is of the order of one skin depth. The potential applications and limitations of the new interference suppressing line are presented.

11. The Electric Stress Grading of Insulator Strings and Their Radio Influence Voltages.  
Denholm, A.G.

Influence of such factors as diameter of tubing of which grading rings are made, distance between two rings, and their vertical position relative to insulator string on stress grading and RIV.

Paper 60-90, AIEE, Transactions on Power Apparatus and Systems, Part III, Volume 79, June 1960, Pages 167-174.
12. The Pulses and Radio Influence Voltage of Power Frequency Corona.  
Denholm, A.S.

Initial results gained in detailed investigation of corona pulses which occur with alternating voltage on short lengths of conductor; examination of pulses which develop at different phases of applied voltage, determination of their true shapes, and measurement of corresponding radio interference voltage.

Paper 60-775, AIEE, Transactions on Power Apparatus and Systems, Part III, Volume 79, October 1960, Pages 698-707.
13. Defense Documentation Center Alexandria, Va. Electromagnetic Shielding, A DDC Report Bibliography.

Bibliography for 1957-May 62, Page 1, ARB10257.
14. Magnetic-Field Pickup for Low-Frequency Radio Interference Measuring Sets.  
Epstein, M.

Magnetic field pickup has been developed utilizing Hall effect in intermetallic semiconductors; unlike loop pickup, sensor responds to magnetic flux density and thus is independent of frequency; when used in conjunction with finite flux collectors; its

Trans. on Electron Devices, Volume ED-8, No. 1, January 1961, Pages 70-77.

sensitivity is  $10^{-7}$  gauss in range of 30 cps to 15 kc/s; details of design and construction are given; device is extremely small in size.

15. Electrical Constants and Relative Capabilities of Bundled Conductor Transmission Lines.

Gabrielle, A.F.

The author gives an excellent analysis of bundled conductor transmission lines in terms of their transmission capabilities versus single conductor lines. The results are tabulated in the form of useful tables and graphs. Inductive reactance, capacitive reactance, surge impedance, bundled conductor or intra group spacing, number of conductors per phase and phase separation. The range of the analysis is such that it is applicable to voltage classes 69 kV to 700 kV. Detailed calculations for all data are given.

Paper 63-71, IEEE, Transactions on Power Apparatus and Systems, Volume 83, January 1964, Pages 78-92.

16. Radio Influence Testing of 70 Miles of 345 kV Horizontal Bundle Conductors.

Graham, R.E.

RI test results on 70 miles of 345 kV transmission lines are presented. The design of the 345 kV transmission line using 954 MCM (thousand circular mils) ACSR (aluminum cable steel reinforced) conductor bundled at 18 inch spacing, the use of standard suspension clamps, triangular space plates, and a horizontal phase spacing of 27 feet resulted in satisfactory RI level without control rings at the conductor hardware assemblies. Attenuation tests show that RI readings at one site are not materially affected by precipitation on a line a few miles away.

Paper 61-1027, AIEE, Transactions on Power Apparatus and Systems, Part III, Volume 80, February 1962, Pages 1022-1030.



17. De-Coupling of Transmission Lines to Radio-Influence Voltage.  
Griscom, S.B.  
Field tests to determine whether several sections of transmission line could be satisfactorily de-coupled or isolated to radio interference using RC decoupler network with resistance shunted, for 60 cps purposes by relatively, high inductance; use of properly designed radio interference filters or decouplers is shown to provide high degree of radio interference isolation between sections.  
Paper 60-1026, AIEE, Transactions on Power Apparatus and Systems. Part III, Volume 79, February 1961, Pages 1066-1073.
18. Effect of Bundle-Conductors Field Influence on EHV Transmission-Line Design.  
Harmon, R.W.  
Description of some control shield designs used commercially at 345 and 460 kV; results of laboratory tests indicating trend of art for multiconductor performance and reduced capital costs are shown possible for towers designed for new suspension hardware developed for multi-conductor bundles.  
Paper 61-171, AIEE, Transactions on Power Apparatus and Systems, Part III, Volume 80, June 1961, Pages 316-326.
19. The Spectrum of Corona Noise Near a Power Transmission Line.  
Helstrom, Carl, W.  
A simple statistical model is proposed for the random currents and voltages induced in a high-tension line by corona discharges. The spectral densities of the voltage and current in the line are calculated from the model, with reflections from the ends of the line taken into account.  
The results can be used to estimate the radio influence of a long power line on the basis of measurements made near a short test line.  
Paper 61-795, AIEE, Transactions, Volume 80, Part III, December 1961, Pages 831-837.

20. Insulation Requirements, Corona Losses and Corona Radio Interference for High Voltage DC Lines.  
Hylten-Cavallius N.  
Insulation tests carried out up to 250 kV, and measurements of corona losses and radio interference made up to 250 to 450 kV are discussed by authors associated with ASEA High Voltage Laboratory Ludvika Sweden; it is indicated that corona losses of higher voltages will be less in dc than in ac system, as in case at lower voltages; radio interference from bipolar line is same or less than from correspondence ac line with same voltage to earth, dc insulators become more polluted than ac insulators.  
Paper 63-998, IEEE, Transactions on Power Apparatus and Systems, Volume 83, May 1964, Pages 500-508.
21. IEEE Radio Noise Subcommittee of the IEEE Transmission and Distribution Committee.  
Transmission System Radio Influence, Paper 31, TP65-65 1965.  
An economic overhead electric power transmission system which produces no radio influence is beyond the present state of the art. However sound engineering and attention to relevant aspects of design can produce a system having an acceptable (or tolerable) influence level. Such criteria as have been proved by research or experience together with accepted practices in instrumentation and measurement of radio influence fields are presented as an aid in planning extra-high voltage lines. Because of many variables and parameters that influence radio noise from power lines, and because the level of a line varies with location and time, it is not presently possible to submit specific design criteria. Revisions in thinking in some aspects of the problem may be anticipated as operating experience is gained at the new extra-high-voltage levels.  
This paper is generally a good summary of the knowledge and experience gained over the past years in the RI field.

22. Description of the Procedures and Equipment for the Suppression and Mitigation of Electromagnetic Interference Voltage to Acceptable Levels.

Hinchman Corp.  
Detroit, Michigan,  
January 58, Page 76.

A description is presented of the procedures and equipment for the suppression and mitigation of electromagnetic interference voltage to acceptable levels. The report includes recommendations on power line components, such as, transmission lines and substation equipment for new and existing transmission lines. Transmission lines up to and including 69 kV are reviewed. All available published studies by others as well as the knowledge gained from phases I, II and III, of the subject contract, were utilized in performing this study. A review of electric power utilities design, construction and maintenance procedures was also made and utilized in determining the recommendations of this report. The procedures and equipment were determined from the above study and review for the suppression and mitigation of electromagnetic interference from overhead transmission lines. The conclusions of this report indicate that these methods and procedures to limit the interference from overhead lines to the acceptable level established in Phase III of this contract, are desirable, feasible, and economically justifiable.

23. Predicting Antennas Role in RFI.  
Jacobs, E.

Electronic Industries  
Volume 19, No. 5,  
May 1960, Pages 96-  
102.

Through good antenna design RF interference problems can be drastically reduced; however, even in antennas of exact same type RF interference levels will vary due to minor differences in tolerance during manufacture; equations are given to predict interference from antennas as well as to facilitate calculations of other antenna parameters.

24. Radio Noise and Corona Loss  
Results from Project EHV.  
LaForrest, J.J.  
Fair and foul weather corona loss and radio noise data from the project EHV line are presented. Insulator loss and the dependence of corona loss on load current are discussed. Corona and radio noise data were logged continuously from three configurations tested at 500 kV and another at 700 kV and analyzed with a computer. They provide a basis for predicting line performance. The radio noise measurements from the test line are correlated with long-line performance.  
Paper 63-94, AIEE, Transactions on Power Apparatus and Systems, Part III, Volume 82, October 1963, Pages 735-750.
25. Radio Noise Aging Characteristics of Small Aluminum Conductors.  
LaForrest, J.J.  
Series of tests on aluminum conductors with smooth, clean, greased, and scratched surfaces to determine their radio noise aging characteristics; energized conductors acquired black coating after week of operation, that stabilizes corona start voltage of new conductors with smooth surfaces; radio noise performance of aged, scratched conductors approaches performance of aged smooth conductors after period of 104 days in energized state.  
Paper 62-251, AIEE, Transactions on Power Apparatus and Systems, Part III, Volume 81, October 1962, Pages 424-428.
26. Radio Noise Studies on Power Lines with the Coronaphone.  
Leslie, J.R.  
Development of coronaphone is reviewed to show that correlation between acoustic noise and radio influence voltage exists; its application to study of power line corona sources on hv lines is discussed; on operating lines up to 230 kV, conductor corona was not found to be major contributor to radio noise field, either in day or wet weather, hardware noise is believed to predominate.  
Paper 64-52, IEEE, Transactions on Power Apparatus and Systems, Volume 83, May 1964, Pages 495-500.

27. Instrumentation for Radio Interference Measurements.  
Lorch, J.  
State of the art in development of RI measuring instruments; three types of noise and field measuring instruments utilizing pulse generators for calibration; power density meter, primarily intended to detect personnel hazard in immediate vicinity of high power radar and communication transmitters; requirements posed to RI measuring instruments.  
Inst. Environmental Sciences-Proc. of Instrumentation for Environment. New York, Metropolitan Chapter, December 10-11, 1959, Page 12
28. Radio Interference from High Voltage Lines.  
Mather, R.J.  
Continuously recorded radio noise data collected from operating lines over a 3 year period are subjected to statistical techniques; some anticipated relationships were established; others failed to be verified; results presented are based on records obtained at 2 hv, levels and with 3 different single conductor diameters.  
Part II - Distribution and Correlation Paper 63-92, AIEE, Transactions on Power Apparatus and Systems, Part III, Volume 82, October 1963, Pages 775-782.
29. Radio Interference from High Voltage Lines.  
Mather, R.J.  
Study to conclude that radio interference from hv lines appears to follow normal distribution, only reliable comparison of level of 2 or more lines being comparison of mean and standard deviation of levels for at least a year, continuous recording appears to be most practical means of acquiring necessary data, random sampling over period to be studied is reliable method of inferring total characteristics.  
Paper 61-729, AIEE, Transactions on Power Apparatus and Systems, Part III, Volume 80, December 1961, Pages 890-896.
30. Natural Noise Fields from 1 cps to 100 kc/s.  
Maxwell, E.L.  
IEEE Trans. on Antennas and Propagation, Volume AP-11, No. 3, May 1963, Pages 339-43.

Vertical electric and horizontal magnetic RMS noise field intensities were measured over frequency of 30 cps to 50 kc/s for all seasons of the year and for all time blocks; this data is combined with that of other workers in field to present natural noise density spectra from 1 cps to 100 kcps for central United States regions; seasonal and diurnal variations at these locations are seen to become small below 1 kc/s 10 ref.

31. Designing RFI-Free Communication Systems.

Mazziotti, I.

RFI susceptibility reduction program is outlined; prediction of various types of interference, design of equipment to achieve minimum of predicted interference, and measurements to determine how well this goal is achieved are discussed.

Electronic Industries, Volume 20, No. 5, May 1961, Pages 114-118.

32. An Investigation of Corona Loss and Radio Interference from Transmission Line Conductors at High Direct Voltage.

Morris, R.M.

The author discusses corona loss and RI generation on one single Drake conductor and on Drake 2-conductor bundle installed on two short (370 ft.) test lines energized up to 600 kV positive and negative. Tests were conducted, under all weather conditions and RI measured up to 10 Mc/s. Corona loss for the two conductor bundle was 0.6 to 0.7 that of the single conductor at the same voltage under all weather conditions. Dry weather, same gradients, showed the bundle had 3.5 times the loss of the single conductor. Negative losses appeared greater than the positive losses, all weather. At positive polarity, the bundle had 1/4 the 1 MC quasi-peak reading of the single at the same voltage.

Paper 63-84, IEEE, Transactions on Power Apparatus and Systems, Volume 83, January 1964, Pages 5-16.

33. Corona Loss Research at Ontario Coldwater Project.  
Nigol, O.  
Description of facilities and program report to date in corona loss investigations on 4 conductor bundles.  
Paper 61-119, AIEE, Transactions on Power Apparatus and Systems, Part III, Volume 80, January 1961, Pages 304-313.
34. Analysis of Radio Noise from High Voltage Lines.  
I. Meter response to Corona Pulses  
II. Propagation Theory  
Characteristics of corona discharges and radio noise meters are described and general approach for radio noise analysis on hv lines established; validity of approach is demonstrated by tests, also used to evaluate and to calibrate radio noise meters in terms of signal to noise ratio and quality of radio reception; theoretical method is presented for determining radio noise levels near hv lines; method is based on corona discharge and measuring instrument characteristics which determine readings of radio noise meters.  
63-1023, 63-1022, IEEE, Transactions on Power Apparatus and Systems, Volume 83, May 1964, Pages 524-541, 554-558.
- 34A. NEMA Standards Publication, "Methods of Measurements of Radio Influence Voltage (RIV) of High-Voltage Apparatus, "Publication No. 107-1964.
- 34B. RI Caused by Particles on or Near EHV Conductors I - Fair Weather.  
Newell, H.H.  
This study was made to identify, photograph, and establish the radio noise importance of the fair-weather coronas occurring on an ac high voltage transmission line conductor. Excursions of fair weather interference to over 10 times the base value of the line noise are attributed to corona plumes from vegetable particles and insects attached to the conductors. Vegetable particles and insects are dielectrics. Their plumes occur on the positive half-cycle  
Paper submitted to IEEE 1965. No. 31, CP 65-133, IEEE Winter Power Meeting, New York February 1965.

of potential. Radio noise from the plumes overrides other corona noises associated with the dielectric particles, overrides the noise from weathered metal protrusions on the conductor strands, and overrides the normal noise from insulators, accessories and hardware. The conductor surface gradient, the total conductor surface area and the rate of gradient decay outward from the surface are important to both particle attachment and severity of plume formation.

35. A Practical Handbook for Location and Prevention of Radio Interference From Overhead Power Lines.

October 64,  
64-9E4-565-R1

Pakala, W.E., Westinghouse R&D Center

Contents (Handbook for Location, Reduction and Prevention of Radio Interference from Overhead Power Lines): Description of interference and discussion of important characteristics. Sources of interference on lines: conductors; insulators; hardware; switchgear and other line apparatus; utilization equipment; and foreign lines and equipment. Location of power line and utilization equipment radio interference sources: Radio receivers for location of interference sources, antennas, procedures in location of power line source and other means of source location. Maintenance of radio interference control. Field surveys. Test method specifications and limits for overhead power lines.

- 35A. "Conducted Electromagnetic Interference Measurement Survey 500-130,000 Volts," Contract NBY-17825, December 1961, U.S. Navy Bureau of Yards and Docks. (Discusses and gives calibrations and test results of capacitor type voltage probes and ferrite core clamp-on current probes for the measurement of radio interference from high voltage lines. Tests made to prove feasibility

W. E. Pakala,  
Westinghouse R&D  
Center.



of measuring interference currents on all high voltage overhead lines with low voltage current probe and radio noise meter in bucket of lift truck with insulated boom. Ferrite current probe designed and built can be used with radio noise meter at ground potential on lines up to 15 kV to ground.)

- 35B. High Voltage Surge Measurements on Stranded Copper Conductor and on Magnetic Tape Wrapped Stranded Copper Conductor.

Pakala, W. E.

It has been found that SiFe magnetic tape contiguously wrapped around a copper conductor increases, to a marked extent, the attenuation of radio frequencies and radio interference pulses travelling along power lines. The purpose of the surge tests reported here was to find out if a magnetic tape wrapped conductor would attenuate high voltage surges, such as produced by lightning. The magnetic tape wrapped conductor was also tested for radio interference (RI) due to corona at 60 cycle voltages up to 150 kV. The frequency spectrum produced of corona generation was obtained and the electric field attenuation laterally from the line measured.

36. The Effect of Negative Corona Upon the Formation of Positive Corona.

Pearson, G.A.

It is shown that when alternating voltage is applied to large electrode configuration, presence of negative Trichel pulse corona creates negative space charge which enhances formation of positive pulses corona.

Contract NBY-32226.  
Dept. of the Navy.  
Naval Civil  
Engineering Lab.  
Port Hueneme, Calif-  
ornia. August 8,  
1963. Westinghouse  
Research Report  
63-928-565-R1.

Paper 61-942, AIEE,  
Transactions on  
Power Apparatus and  
Systems. Part III,  
Volume 80, 1961,  
Pages 847-850.

37. **Method of Evaluating Corona Noise Generation from Measurements on Short Test Lines.**  
Perz, M.C.  
Background and underlying assumptions of modern analyses applied to corona noise are reviewed; methods proposed to compute noise current generated per unit length of conductor from quasi-peak value of field intensity, measured under phase conductors in center of open ended test line; in this method, measurements are taken at frequencies corresponding to minima of standing waves, minima being insignificantly affected by line attenuation.  
Paper 62-1405, AIEE, Transactions on Power Apparatus and Systems. Part III, Volume 82, December 1963, Pages 833-844.
38. **Pulses and Radio-Influence Voltage of Direct Corona.**  
Rakoshdas, B.  
Behavior of range of conductor sizes, both smooth and stranded, is examined, at both positive and negative polarity, for better understanding of factors contributing to dc and ac radio interference, characteristics examined included shape of corona pulse, amplitude and charge context of pulse, repetition rate, RIV caused by pulses at 1 Mc/s and frequency spectra of RIV.  
Paper 63-999, IEEE, Transactions on Power Apparatus and Systems, Volume 83, May 1964, Pages 483-491.
39. **Radio Interference Studies for Extra-High-Voltage Lines in Ontario.**  
Reichman, J.  
The authors cover the aspects of constructing an EHV test project for the purpose of studying the RI generation at Coldwater, Ontario on the Hydro-Electric Power Commission of Ontario facilities. Their contention is that a number of prior attempts were made to correlate RI to conductor gradient. Their findings at that time showed that the literature and their tests were difficult to correlate. It was concluded that gradients as high as 18.8 kV/rms cm or slightly higher were entirely practical and  
Paper 60-95, AIEE, Transactions on Power Apparatus and Systems, Volume 79, June 1960, Pages 153-160.

40. Radio Influence Studies on Extra-High-Voltage Lines  
Reichman, J.  
Progress report on studies and tests by Hydro-Electric Power Commission of Ontario on two test lines at Coldwater, Ontario; lines are capable of operation up to 600 kV and are each approximately 2500 ft. in length; they use four conductor bundle construction with 1.1 and 0.8 in. diameter conductors respectively.  
Paper 61-161, AIEE Transactions on Power Apparatus and Systems, Vol. 80, June 1961, pp. 261-270.
41. A Summary of Radio Interference Studies Applied to EHV Lines  
Reichman, J.  
Source and nature of corona discharges on EHV lines, and effect on RI meters is reviewed; relationship between conductor diameter and operating gradient is given; propagation experiments and mode analysis of radio noise on Coldwater test line, using artificial sources, are described, results of long time RI recordings on 500 kV test line and close to 230 kV circuit are compared.  
Paper 63-1024, IEEE Transactions on Power Apparatus and Systems, Vol. 83, March 1964, pp. 223-228.
42. A Summary of Radio Interference Studies Applied to EHV Lines  
Reichman, J.  
The authors summarize the efforts of approximately five years investigation of RI Studies on the Hydro-Electric Power Commissions test lines at Coldwater, Ontario. Tests involve single and bundled conductors of varying size operating at various voltages between 300 to 600 kV. They conclude small diameter conductors in bundles have the advantage from the RI viewpoint over larger conductors for the same gradient. Hardware contributes more to RI than do conductors. (provided conductors are damage free and uncontaminated) QP meters respond only to the largest corona sources. RI levels on EHV lines should be no greater than that from existing HV lines in both fair and foul weather even at increased operating gradients.  
Paper 63-1024, IEEE Transactions on Power Apparatus and Systems, Vol. 83, March 1964, pp. 223-228.

43. Leadville High Altitude Extra-High-Voltage Test Project - Part I - Report on 4 Years of Testing.

Robertson, L. M.

The transmission system in the west of the state of Colorado includes several lines crossing the continental divide at altitudes of up to 13,000 ft. Operating difficulties include severe weather conditions, high frequency of lightning strokes, high tower footing resistance and remoteness. The increase in system loading demands an increase in operating voltage and the Leadville project was initiated to provide optimum design parameters for peculiar high-altitude conditions. The testing site at 10,500 ft. includes a variety of towers supporting a number of single and two and four conductor bundle conductors to operate at either 230 kV or 345 kV. Results show that conditions as represented by radio influence and corona losses are not as severe as expected from extrapolation of data obtained from the Tidd or other low-altitude testing stations.

At Leadville blackening of the conductor and the usual "aging" effects were not observed. This precluded the segregation of altitudinal and conductor surface effects.

44. Leadville High-Altitude Extra-High-Voltage Test Project Part II - Corona Loss Investigations

Robertson, L. M.

Experimental results at over 10,000 ft. in exceptionally clean air conditions have shown single phase corona losses to be considerably less than those predicted from other investigations, or by the "Peek" or Peterson formula. In the absence of air-borne pollution conductor-losses did not change with time and blackening of the conductor did not occur. Under these conditions the dependence of the losses on the air density factor ( $\delta$ ) followed  $\delta$  or  $\delta^{1/2}$  rather than the more usual relationship of  $\delta^2$ . Major increases in corona losses were only associated with falls of rain or snow.

Paper 61-236, AIEE Transactions on Power Apparatus and Systems, Part III, Vol. 80, Dec. 1961, pp. 715-725.

Paper 61-263, AIEE Transactions on Power Apparatus and Systems, Part III, Vol. 80, Dec. 1961, pp. 725-732.

45. Leadville High-Altitude Extra High Voltage Test Project, Part III, Radio Influence Investigations  
Robertson, L. M.  
If radio influence levels are plotted on the basis of dB above a reference of  $1 \mu\text{V/m}$ , an almost straight line relationship is obtained. This relationship takes the form of  $\text{dB} = k (V - V_0) + \text{dB}_a$ .
- Where  $k$  is a representative constant of the conductor;  $V_0$  is the voltage threshold for increase in noise level. The critical voltage decreases with altitude and depends upon  $\delta^{1/2}$ , where  $\delta$  is the air density factor. Comparison between Leadville results and those from low altitudes show that difference of altitude does not appreciably affect lateral attenuation.
- Paper 61-236, AIEE Transactions on Power Apparatus and Systems, Part III, Vol. 80, Dec. 1961, pp. 732, 743.
46. Leadville High Altitude Extra-High-Voltage Test Project - Part IV - Conductors, Towers, Insulators and Substations  
Robertson, L. M.  
Tests at 10,500 feet show that high altitude transmission lines to operate at 230 kV or 345 kV present few additional design difficulties over conventional lines. Single or bundle conductors may be used with conventional joints, spacers, fittings and insulators.
- It is possible to use wooden cross-arms with unearthed insulator strings should towers with improved lightning performance be required.
- Paper 61-236, AIEE Transactions on Power Apparatus and Systems, Part III, Vol. 80, Dec. 1961, pp. 743-748.
47. Leadville High Altitude Extra-High-Voltage Test Project - Part IV - Conductor Tests  
Robertson, L. M.  
Corona loss and radio influence levels from 2 year testing on conductors, designed to bracket. 230 kV operating range at high altitudes, indicates that smaller conductors than originally estimated will perform adequately; results of HF tests gives values for radiation, and attenuation in 10-200 Mc/s range; mechanical observations show conductor oscillations which are produced by heavy corona and damp conducto conditions.
- Paper 62-1096, AIEE Transactions on Power Apparatus and Systems, Part III, Vol 81, Feb. 1963, pp. 939-944.

48. Bibliography on Bundled Conductors  
Sandell, D. H.  
Paper 61-871, AIEE Transactions on Power Apparatus and Systems, Part III, Vol. 82, Dec. 1963, pp. 1115-1128.
49. 345 kV Wood Pole Test Line - Radio Influence and Leakage Current Investigation  
Schroeder, T. W.  
Tests are described performed on Illinois Power Co. one mile test line to ascertain whether wood pole H frame structure configurations, which had been successfully used for 138 kV lines, could be extrapolated to 345 kV lines; RI measurements were made with line energized both 3-phase and single phase, on which leakage currents and hot line maintenance techniques were studied; paper reports results and analysis of these aspects in detail.  
Paper 63-1021, IEEE Transactions on Power Apparatus and Systems, Vol. 83, March 1964, pp. 228-236
50. Radio Interference Attenuation on Energized High-Voltage Transmission Lines, Measurement and Application  
Stone, L. N.  
Method of predicting additive effect of individual radio interference sources; data on attenuation of RF energy from corona sources on energized HV lines. Paper 59-814.  
AIEE - Trans. Vol. 78, Part III, (Power Apparatus and Systems) n. 45, Dec. 1959, p. 1238-45. Discussion p. 1245-7.  
The test circuit consisted of a single unit 350 kV test transformer, high voltage coupling capacitors and terminating network.  
The recording instrument was a Stoddart Radio Interference and Field Intensity Meter model NM20B.

51. The Apple Grove 750 kV Project - 775 kV Radio Influence and Corona Loss Investigations

IEEE Transactions  
Paper 31-TP-65-151

Taylor, E. R.

The Apple Grove Project has three test lines approximately 2400 ft. in length, each consisting of four conductor bundles. Different conductor diameters are used in each line; line A 1.382 in. diameter, B 1.192 in diameter C 1 in. diameter as these are considered to bracket the conductors that will be used for 200/750 kV transmission. Light load currents are simulated by circulating heating current. RI and corona loss data can be recorded automatically every 2 or 20 minutes on magnetic tape. Similarly with weather data. All three lines are compared under the same conditions. Initial data, 1.382 inch diameter conductor RI of 47.6 dB above 1  $\mu$ V/m at 100 ft. with a deviation of 6.7 dB; 1.10 inch diameter 50.6 dB; 1" 59 dB. Foul weather corona loss 27 to 365 kW/3 ph. mile. In foul weather corona loss and RI may be at times higher on the larger conductor than the smaller.

52. An Investigation of Radio Influence Voltages on Transmission and Distribution Lines on the Same Right of Way

Paper 62-1367-AIEE  
Transactions on Power  
Apparatus and Systems,  
Part III, Vol 81,  
Feb. 1963, pp. 1062-1066

Taylor, F. L.

Field investigations of radio influence voltages on distribution circuits caused by parallel HV lines; attenuation factors for spacings between lines, between primary and secondary of distribution transformers, and attenuation along distribution laterals were determined for service conditions; noise reaching customer and acceptable signal to noise ratios are indicated.

53. Analytical Prediction of Electromagnetic Environments

IRE Transaction on  
Communications Systems  
V. CS-9 n2, June 1961  
p. 175-85

Tetley, W. H.

Three approaches used by military agencies to predict status of future electromagnetic environments are described; in all cases, basic technique of analytical prediction calls for solution of mathematical models by digital computer.

54. Equigradient Lines in the Vicinity of Bundle Conductors

Timascheff, A. S.

A method to determine the potential gradient values at any point in the vicinity of the subconductor grouping of a bundle conductor with any number of subconductors is presented. Charts are also given for which the (relative equigradient lines (field strength values) corresponding to the series of points of constant gradient values within the subconductor grouping for two, to six conductor bundles. The charts are arranged for both near vicinity and far vicinity.

Paper 62-1369, AIEE Transactions on Power Apparatus and Systems, Part III, Vol. 82, April 1963, pp. 104-110

55. Effective Dielectric Constant of the Atmosphere During a Snow Storm and its Influence Upon Corona Losses

Timascheff, A. S.

Tentative explanation is given of fact observed particularly in Canada, that amounts to heavy corona losses during snowstorms, sometimes exceeds those during rainstorms; explanation is based on consideration of "effective dielectric constant" during precipitation; calculations and model measurements indicate large difference between rain and snow; surface potential gradient during heavy snowstorms may be increased by as much as 10% to 20%.

Paper 64-39, IEEE Transactions on Power Apparatus and Systems Vol. 83, May 1964, pp. 492-495

57. Field Patterns of Bundle Conductors and their Electrostatic Properties

Timascheff, A. S.

Method for calculation of field pattern of n-subconductor bundle, particularly when using medium size digital computer; examples of patterns for 2, 3, 4, and 6 subconductors and for average values of subconductor distance to subconductor radius, derivation only from consideration of field patterns, of radius of single conductor with capacitance equivalent to bundle capacitance.

Paper 61-740, AIEE Transactions on Power Apparatus and Systems Part III, Vol. 80, pp. 590-597



58. Graphical Method Predicts Radio Influence      Electronics V. 34, n5  
Vogelman, J. H.      Feb. 3, 1961  
pp. 60, 62, 64, 66  
Graphic-manual method of interference prediction is described which involves series of sorting operations in which interference pairs (interference and interfered with) are gradually reduced in number until only significant ones remain.
59. Traveling Waves on Power Transmission      IEEE Transactions  
Lines with Special Emphasis on Radio      Paper 63-1020  
Noise  
Wagner, C. F.  
Traveling waves on polyphase transmission systems can be resolved into component waves in various manners. It is shown that for voltages below the corona threshold value, the resolution into a ground-current component and conductor components is susceptible to simple analysis because with this resolution one of the components, the ground component, has a high attenuation and distortion that is dependent almost entirely upon induced currents in the earth. Application of this type of resolution to the radio noise problem is discussed briefly.
60. Practical Approach to Interference Pre-      Electronics V. 33 n37  
diction and Suppression      September 9, 1960,  
Wilson, P. B.      pp. 84-87  
Methods for estimating system interference problems and preventing them are presented; problem is examined by first considering circuit cards, then sub-assemblies, then combining of sub-assemblies into system package.

AIR FORCE CONTRACT A.F. 30-602-3822

APPENDIX VII PART (3)

RADIO INTERFERENCE - HIGH VOLTAGE POWER LINES

AMERICAN LITERATURE PRIOR TO 1960

The literature is mainly in abstract form and arranged alphabetically by means of the authors' name or by institute, association etc. In a few cases additional references were numbered using letter A or B suffix.

Pages 73 to 88 contain abstracts. Pages 89 to 95 references mainly not abstracted.

1. Adams, G. E., "Radio Interference from High Voltage Transmission Lines as influenced by Line Design" - AIEE Trans, pt. III, April 1958, pp. 54-63.

Results of calculation procedure as reported previously and are intended to show effect of principal items of line design upon interference level: vertical versus horizontal configuration, interphase spacing, center-to-center spacing between conductors of a bundle, and conductor phasing and circuit separation for double-circuit lines. Effect of attenuation of RI level as calculated. Single conductor, 3-phase, double circuit line. Discussion: Mention of Swedish method of calculation which compares well with Adams' but is simpler. Table of limit versus conductor size and phase spacing given.

2. Aggers, C. V. and Pakala, W. E., "Measuring Radio Interference from High-Voltage Apparatus", Electric Journal, December 1933.

Describes test results with coupling capacitor used up to 60 kV to measure conducted voltage up to 0.60-1.5 Mc/s. Effect of changing resistance in series with coupling capacitor from a few ohms to 1200 ohms. Description of choke coils used and their impedance curves.

3. Aggers, C. V. and Stoddard, R. N., "Suppression of Radio Interference using Tuned Choke Coils". Electric Journal, 1934, Vol. 31, pp. 305-307, 367-370.

Discussion of design of choke coils for audio, carrier and radiobroadcast frequencies.

4. Aggers, C. V., and Pakala, W. E., and Stickel, W. A., "Effect of Radio Frequencies of a Power System on Radio-Receiving Systems". AIEE Trans., Vol. 62, 1943.

Describes measurements on distribution lines and gives curves of coupling factor of AM broadcast antennas to power lines.

5. Atta, E. V., and White, E. L., "Radio Interference from Line Insulators", Journal AIEE, September 1929, pp. 682-86.

General discussion of RI from high-voltage equipment, pin type insulators, suspension insulators. Gives attenuation curves perpendicular to and along 55 kV line for wet and dry weather.

6. Brown, R. D., "Radio-Noise Source Aids in High Voltage Studies", Electrical World, April 1, 1957, p. 72.

Description of suspension insulator with 0.1 inch spark gap connected across it for noise source. Holes in porcelain for mounting spark gap. Gap of brass machine screws filed to a point. Frequency spectrum of this source extends into TV bands.

7. Cheek, R. C., Moynihan, J. D., "A Study of Carrier Frequency-Noise on Power Lines" - Part I Theoretical Considerations and Measuring Techniques, Vol. 70, Pt. II, 1951, pp. 1127-34, AIEE.  
Part II Results of Field Measurements, Vol, 70, Pt. II, 1951, pp. 1325-34.

I. Characteristics of noise and response at receivers.  
Discussion of noise meters.

II. Results of series of measurements of conducted carrier frequency noise levels on lines from 23 to 230 kV. Used Conventional coupling capacitor in series with drain coil and Stoddart NM10A meters. Variation of noise with frequency and weather.

8. CISPR (Canada) 302 5-10-594 Department of Transport, Ottawa, Canada.

Incidence and Nature of Power Line Interference  
(Not for Reproduction)

Given number of sources, service interfered with, line voltages, types of sources and degree of interference in microvolts per meter. (Some of these sources such as non-current carrying parts caused interference to TV. There may be no correlation with TV frequency voltage on conductors to radiated interference on these types of sources.)

9. CISPR (Japan) 304 - Power Line Radio Interference

Describes radiated and conducted tests on distribution and high voltage circuits at 0.6 and 1.4 Mc/s and conducted tests at 1 Mc/s on insulators. Mean values and standard deviations are given of quasi-peak (1/600) for 0.6 and 1.4 Mc/s of nation-wide variation of the Maximum Noise intensity of Distribution Line RI.

10. CISPR (Sweden) 312 - Radiation from Power Lines

Discusses damping and spreading conditions, dependence on frequency etc. Proposals are discussed concerning permissible interference limits and methods of measurement. Measuring frequencies of 0.16, .54 and 1 Mc/s are chosen.

11. CISPR (Suisse) 305 - 1958 Contribution to the Estimation of Radio

Interference from Power Lines by J. Meyer de Stadelhofen and W. Walter (Bern).

The authors describe measurements with CISPR meter on power lines and laboratory measurements on power line components. Conducted measurements were made at 1 Mc/s using capacity coupling and 300 ohm loading. Radiation and attenuation measurements up to 6 Mc/s.

12. CISPR (Germany) 308 - Radiation from Power Lines. (Not for Reproduction)

Includes along with radiated measurement methods a conducted measurement circuit using coupling capacitor and 150 ohm load for line components. Measurements at  $0.250 \pm .05$  Mc/s  $0.450 \pm .05$  Mc/s are proposed.

13. CISPR (U.S.S.R.) 304 - 1958 Radio Interference From Lines

This report includes conducted test circuit similar to NEMA 600 ohm circuit. Radiation measurement data on 240 and 400 kV lines up to 150 Mc/s are given.

14. CISPR/B/WG3 (Munich) 1 - Measurement of Interference from Power Lines

A tabulation is given of test frequencies and load resistance values etc. used by several countries for conducted measurements of high voltage apparatus. The highest test frequency is 1 Mc/s. It is proposed to use coupling capacitor method for frequencies below 30 Mc/s. For frequencies above 30 Mc/s it is stated that current measurements only are suitable.

15. CISPR ( Secretariat) 416, July 1959. (Not for reproduction)

The CISPR concluded that its discussion on the outcome of the meetings of the CISPR Sub-committee B Working Group on measurements of interference from power lines, held in Munich, June 1958, has confirmed that there is insufficient experience to enable a specification to be prepared for the measurement of voltage on high voltage lines and equipment at frequencies above 30 Mc/s. - Decides that the following question should be studied: What are the characteristics of a measuring system suitable for the measuring of the interference voltage produced by high voltage lines and equipment at frequencies above 30 Mc/s?

16. Corbett, W., Radio Interference Problem, the Power Co. AIEE Journal, October 1925, p. 1057.

General discussion and explanation for need for RI considerations. Classes and courses.

17. Fabre, M. J., "Experimental and Theoretical Study of the Mechanism of Propagation and Radiation of Radio Noise Emitted by High Voltage Lines" Bulletin, Society Francaise des Electriciens, Seine, France, Vol. 3, #31, July 1953, pp. 419-24.

RI spectrum, attenuation, long and short lines.  
Theoretical analysis of impulse spectrum.

18. Flex, Edgar H., "The Radio Engineer's Responsibility in Coping with Man-Made Interference". Proc. of IRE, Vol. 17, 1929, pp. 1385-89.

General discussion, no data.

19. Forrest, V. J. and Martin, R. E., "Appendix, Laboratory Methods for the Measurement of Radio Interference from High-Voltage Insulators and Other Plant" part of "Progress Report of Study Committee on Insulators (No. 5)" by G. H. Gillam CIGRE #215, 1958.

General discussion of measurement methods in measurement of interfering field (radiation), with NEMA test circuit (cap. in series with 600  $\Omega$  and RF choke in power supply), and measurement of RF current in earth circuit from bottom of insulator.

20. Foust, C. M. and Frick, C. W., "Measurements Pertaining to the Coordination of Radio Reception with Power Apparatus and Systems", AIEE Trans., June 1943, Vol. 62.

Compares radio noise meters and gives data on radio influence voltage from high voltage apparatus. Discusses test voltages and limits when measured with the NEMA 107 conducted measurement circuit. Gives curves of under line antenna radio influence voltage ratios and discusses the relations of RIV of apparatus to radio-receiver noise.

21. Ghesquiere, J. D. and Bennett, S. A., 4th Conference on Radio Interference Reduction 1958. - Measurements of Electromagnetic Interference on High Voltage (50 kV) Transmission Lines.

This paper reports on a study of electromagnetic interference from high voltage transmission lines performed by the Hinchman Corporation under Bureau of Yards and Docks Contract.

Describes radiated and conducted measurements on lines in service. Radiated measurements were made from 30 cps to 1000 Mc/s. No measurable radiation obtained above 25 Mc/s. Conducted measurements made with 66 kV porcelain encased 0.005 mfd capacitor mounted near conductor by suspension from cross-arm. A 600 ohm resistor with 50 ohm coax across 50 ohms to ground level and terminated there in 50 ohms. This conducted method proved satisfactory from 0.015 to 25 Mc/s. Calibrated in the laboratory with signal generator. No correction factors for coupling system given in this paper.

22. Gill, A. O. and Whitehead, S., "Electrical Interference with Radio Reception", Journal IEE, 1938, 83, p. 345.

Nature of interference: signal to noise ratio. Measurement of interference (radiated). Comparison of various methods. Sources of interference: trolley-buses; HV overhead transmission lines high frequency apparatus, electric elevators, telecommunication apparatus, domestic items. Methods of suppression at source and at receiver. Gives field strength beneath 132 kV line up to 20 Mc/s and attenuation out 0.6 miles and up to 18.5 Mc/s.

23. Jancke, G., Holmgren, B., Pettersson, G. A. and Akerland, P., "Protective Measures Against Telephone and Radio Interference from High Tension Lines", CIGRE 338, 1954.

General discussion of RI phenomena. "As a general estimate for broadcast reception a signal to noise ratio of about 40 dB gives reception entirely free from interference whilst a ratio of about 30 dB will give relatively satisfactory reception. For a signal field strength of 1000  $\mu\text{V/m}$  interference field at receiving aerial should amount to 10  $\mu\text{V/m}$  maximum for undisturbed reception and 30  $\mu\text{V/m}$  for fairly acceptable reception". Measurements made with a "frame aerial". Damping of field perpendicular to line: reduction at 50 m, 22 dB; at 100 m, 32 dB; at 200 m, 42 dB. For 220 kV and 380 kV lines gradient about 15 kV/cm rms but "conductor diameter should be selected where possible so that a lower field strength is obtained which may be estimated at 13 kV/cm". Measures for reducing effect of RI.

24. Jenssen, M., "On Radiation from Overhead Transmission Lines", Proc. of IEE, Vol. 97, Part III, 1950, pp. 166-178.

The general problem of radiation from lines is discussed and the theoretical background is sketched. The radiation is calculated by the usual approximate method, i.e. the current distribution of the principal wave in an infinite line is first determined, and the radiation field of a finite line is then calculated on the assumption that the current distribution is the same. The method is applied to lines in free space, to single-wire lines above earth of finite conductivity (earth-return lines), and to multiple



lines above earth of finite conductivity. The current distribution and possible wave types in some typical multiple-lines are analyzed. It is shown that only the wave in the earth-return line, and the corresponding wave type in the multiple line, will produce appreciable radiation. Formulae for calculation of this radiation field are given, and experimental results are described. Conclusions are drawn regarding interference in carrier-line systems and the use of long-wire transmitting antennae.

25. Jespers, P., "Calculation of the Level of Interference Carried by a High Voltage Line in the Event of Faults Producing Flashovers in a Chain of Insulators" CIGRE #314, 1958.

Theoretical examination of build-up of spark impulses considering chain of insulators and faulty joints as capacitors. By Laplace methods derives area under-pulse corresponding to its spectrum density. Checks results with lab tests.

26. Hinchman, "Report of a Review of Past and Current Work on Electromagnetic Interference Voltage from Electric Power Transmission Lines" - 23 November 1955, Hinchman Corp.

General summary of references indicating mechanism of corona and RI. Effects of conductor diameter, spacing and height, ground wires, line termination and length, frequency, attenuation; line hardware and insulators, weather, choke coils. Gives standards and measurement methods including Joint Coordination Committee Standard (NEMA Circuit-107) for conducted RIV measurements.

27. Hinchman Corp. "Report and Criteria of Method of Measurement and Recommended Allowable Limits of Electromagnetic Interference Voltages from High Voltage Transmission Lines" 25 October 1957.

Correlates information obtained during field studies of a number of 91.6 kV overhead lines of radiated (30 cycles to 1000 Mc/s) and conducted measurements (15 kc to 25 Mc/s), and "establishes levels of radiated and conducted

interference from acceptable economically - designed and maintained overhead transmission lines up to 66 kV". Used Stoddart URM-41, URM-6, PRM-1A, URM-47, URM-17 receivers. "Above 25 Mc/s, there was no measurable interference", from well-maintained transmission lines". "It is concluded that high frequency interference is not inherent in well designed and properly maintained transmission lines." Readings taken under line and at 25 and 50 ft. Used URM-6 and PRM-1 for conducted measurements, at 1 Mc/s coupled through coupling capacitor in series with 600 ohm variable resistor (NEMA circuit) paralleled by coil. Due to mismatch resorted to 0.005 mfd. in series with 550 in series with 50 ohm coax. but indicated as hazardous. For safety resorted to capacitor mounted on pole with coax. shunted with 50 ohms and safety cutout to ground. Calibration difficult above 4 Mc/s and becomes unreliable below 0.015 Mc/s.

Radiated tests on 41.6 kV lines of types of construction: flat with pin insulators, flat with post insulators and shield wire with post insulators. Nine test locations on lines of various age and load, wooden poles and cross-arms, length in excess of five miles, test spectrum from 30 cps to 15 kc with loop and vertical rod under line at 25 and 50 feet and with horizontal dipole under line from 25 Mc/s to 1000 Mc/s.

Conducted tests at 6 locations simultaneous with radiated.

Gives "Military Criteria" for radio interference measurements, methods and limits (14 kc to 1000 Mc/s) for overhead lines to 66 kV.

28. Dwitht, H. B., "Some Aspects of Surface Voltage Gradients on Power Transmission Lines", AIEE Trans., Vol. 76, Part II, December 1957, pp. 1217-1219.

Discussion of separate design for each phase to reduce gradient. Three-phases at same height gives gradient on center conductor, for grounded neutral, 7% higher than outer conductors. Gives formula for ratio of difference in rms values of charge of middle and outer conductors. Example given where radii of outer conductors is decreased by 8.5% to make gradients of all conductors equal to that of middle conductor. "Calculations made for only one phase, as though the other phases were absent or at an infinite distance, can be in error by a large percentage". Example

where calculations give result 21% too low. "Indoors, under a roof with metal beams the amount and distribution of charges may be strangely affected and measurements would be different from those on an outdoor line". With conductors per phase, one above the other: "difference between charges of two (sub-conductors) is --- less than 1%".

29. Hinchman Corp., "Description of the Procedures and Equipment for the Suppression and Mitigation of Electromagnetic Interference Voltage to Acceptable Levels", 26 January 1958.

States that "Limits of interference have been established at 15 microvolts per meter at 157,000 feet from the apparatus". Sources RI on sub-transmission lines (12 kV to 69 kV) are given as insulators, tie-wires, conductors, poles cross-arm hardware, guy wires, ground wires, power equipment and apparatus, corrosion and contamination. Gives percentage figures of RI sources from Canadian report. Recommended construction practices to reduce RI. Methods and hints for detection of RI sources. Recommended practices and specifications.

30. Cooke Engineering Company, "Electronic Interference Surveys of Automatic Telephone Equipment", Final Report - Contract NBY-13014, Bureau of Yards and Docks, 8 March 1958.

Aural monitoring of RI-FI meters, rf voltage and current measurements in frequency range from .014 to 1000 Mc/s using receivers AN/URM-6, AN/PRM-1, AN/URM-47, AN/URM-17 and Cooke Engrg. Co. calibrated test toroid for measuring noise currents. Radio Frequency interference voltage measurements of (1) conducted interference levels between pairs on telephone lines and (2) between one side of line and ground; noise currents on load sheaths; radiated rf levels. Radiated measurements inside exchanges with vertical rod in frequency range from 26 to 400 Mc/s or with horizontal half-wave dipole antenna.

31. Hinchman Corp. "Report and Criteria of Method of Measurement and Recommended Allowable Limits of Electromagnetic Interference Voltages from High Voltage Transmission Lines of the 132 kV Class", 22 September 1958.

Similar in wording and content to report on 66 kV class and used same instruments. No measurable radiated interference in frequency range of 25 to 1000 Mc/s. Conclusion: A fairly accurate evaluation of conducted interference can be made from radiated interference measurements. The need for more accurate measurement of conducted interference does not appear to justify the large expenditures of time and money that would be required. Radiated interference from 120 kV 3-phase overhead lines at 12 locations in southeast Michigan. Types of construction: - steel tower, steel pole, wood H-frame; four conductor sizes - 3/0 copper, 266.8 MCM ACSR, 477 MCM ACSR and 795 MCM ACSR; in excess of 5 mile lengths from 30 cps to 1000 Mc/s. From 30 cps to 15 kc under line with loop and rod antenna 25 and 50 feet from line, 14 kc to 8 Mc/s horizontal with loop 25 and 50 feet from line, 25 to 1000 Mc/s with dipole under line.

Includes "Military Criteria" for RI measurement, methods and limits (14 kc to 1000 Mc/s) for overhead lines from 70 kV to 132 kV omitting conducted measurements.

32. Hinchman Corp., "Description of the Procedures and Equipment for the Suppression and Mitigation of Electromagnetic Interference Voltages from Transmission Lines of the 132 kV Class to Acceptable Levels" 5 November 1958.

Similar to wording and content in report for 66 kV class. Includes recommended specifications similar to those recommended for 66 kV class.

33. Hoshiai, G. T., T. Yamada, Mita, N., Yoshion, S., "Radio Interference Research in Japan with Special Reference to EHV Transmission Lines", Paper No. 403, CIGRE, Paris, France 1956.

"59 dB and 45 dB are representative values for RI for fair weather directly under the conductor for 410 mm<sup>2</sup> and 520 mm<sup>2</sup> ACSR respectively at 250 kV operating voltage". Used noise meters similar to Ferris - 32A. Gives RI (radiated) under line on Tanashi Test Line: 35.0 mm diam., 34.2 mm diam., 28.5 mm, 25.33 and 2 X 240 mm<sup>2</sup>/40 cm (22.4 mm diam.) ACSR. Curve of effect of humidity increasing from low values at 50% to about twice at 86%. Effect of rain. Relation between single and 3-phase lines: "RI on 3-phase line is about 2 dB higher than that on single-phase line at same surface gradient". Give an empirical relation between RI and conductor surface gradient. Found little difference in RI from horizontal and vertical configurations even though surface gradient higher for vertical - attributed to unfavorable weather during measurement on horizontal.

34. Langdon, J. L. and Bradshaw, E., "Radio Interference from Discharges on High-Voltage Line Insulators". Journal IEE, 1934, Vol. 75, p. 643-652.

Laboratory field investigations. Measured discharges through series air core transformer to thermionic voltmeter. Pin and suspension-type insulators. Effect of rain and humidity. Field meter consisted of vertical rod antenna to receiver from which voltmeter measured in wave lengths 300-500 and 1000-1800 meters.

35. Leslie, J. R. and Jones, D. E., "Interference Studies on 250 kV Wood-Pole Circuits - Use of over-sized Center Phase Conductor" CIGRE 1958, No. 309.

Studies of Radio and TV interference from 115 kV wood-pole line converted to 250 kV and from one mile test line using bunched conductors and small inter-phase spacing. Measurements with Ferris 32 B at 1 Mc/s showed converted line noise increase of five times that of standard 230 kV line. Laboratory investigations of insulator noise showed that their radio interference production was negligible. Measurements at 50-250 kV at base of carrier coupling capacitor at end of line was 20 dB higher than normal. Used a meter with 5-element Yagi antenna on truck for TV interference tests. Also, VHF probe tuned to about 18 Mc/s fastened to line-line stick used to localize

individual noise sources. TV interference decreased to negligible value during rain. Metal-to-metal sparking reduced by tightening hardware resulting in decrease of level by a factor of 10.

Test line: bundle conductor 477 MCM spaced 9 in. in vertical direction using conductors from converted line. Two ground wires. RF choke coils. Voltage 230-270 kv. Measurements under line and 50 feet away given in curve at 1 Mc/s for 230-270 kv.

Surface factor of 0.79 chosen by experience. Economics of oversized center phase conductor: reduction in spacing from 25 to 18 ft. by using 8% larger in diam. cond.

Use of 18 ft. phase spacing: 795 MCM for all 3 phases in unpopulated areas (corona voltage 237 kv) 1192.5 MCM (1.338 in. diam.) in densely populated areas and for center conductor for 7 miles either side (corona voltage 276 kv) and used 795-1192-795 MCM for phase conductors in sparsely populated areas (corona voltage 252 kv) and 2 dB attenuation per mile.

36. Leslie, J. R., and Woodington, P. W., "Field Studies of Noise at Television Frequencies from Power Circuits", AIEE Trans. Part III, August 1956, pp. 656-661.

For wood poles lines UHF noise is generally caused by noncurrent-carrying metal parts which have become loose. Insulators, including untreated type, usually quiet. Transmission circuits are generally quiet, except where suspension insulators are used as jumper supports. Survey of 148 poles of 12 kv construction, loose ground wires and staples and loose cross-arm braces and double arm spacer bolts responsible for significant UHF noise. Three loose insulator pins (steel), a split insulator and open fuse contact which was swinging in the wind. At 200 megacycles at 20 feet from pole measured 100 and 2000 microvolts per meter when tapped gently with mallet. "Radio noise (1 Mc/s) under line was usually not increased by loose hardware, insulator noise predominating to give measured level of 16  $\mu\text{v}/\text{m}$ . Loose ground wires gave rise to 1 Mc/s as great as 4000  $\mu\text{v}/\text{m}$ , one-half to a span away." Noise mechanism: - steel cross-arm braces as half wave dipole - quite broad-banded.

37. Lippert, Pakala, Bartlett, Fahrnkopf, "Radio Influence Tests in Field and Laboratory - 500 kV Test Project of the AGE Co." AIEE Trans. Vol. 70, Pt. I, 1951, pp. 251-69.

Gives RI data for test line on several conductors as a function of line voltage up to 525 kV. Effects of weather on chart records. Effects of line termination, changing of line length and local source on conductor, and distance from line. Single phase to three phase comparison with peak, quasi-peak, and average detectors. Comparison of Stoddart and Ferris meters. Radiation tests from 0.015 to 120 Mc/s. Gives conductor diameter versus line voltage for 32 foot horizontal spacing. Laboratory tests on weathered and new conductors dry and with artificial rain using NEMA 107 measuring circuit. Signal to noise ratios for several qualities of reception using Stoddart and Ferris meters and corona type radio noise.

38. McMillan, F. O., "Radio Interference from Insulator Corona", AIEE Trans., V. 51, 1932, p. 385-91.

Loop tests in Laboratory.

39. McMillan, F. O., "Some Characteristics of dc Conductor Corona", AIEE Trans., Vol. 54, 1935, pp. 282-292.

Laboratory study of polarity characteristics of ac corona on polished, weathered, mutilated and contaminated conductors 0.999 to 0.422 inch diam. copper 0.565 inch diam. aluminum and other diameters. The positive corona current, which increases at a much lower rate than the negative, does not produce rf oscillations except under special conditions of conductor contamination or abnormal mutilation.

Oscillograms of voltages between conductor and plane and audio frequency output of super heterodyne receiver with loop and picking up 1 Mc/s radiation. Curves of corona current versus voltage to ground plane. Corona started on weathered copper conductor 92-93% that on polished conductor and started at 85-86% for weathered aluminum. Field strength of radiation higher for polished conductor than for weathered at corresponding voltages and rate of current rise considerably higher for polished

conductors. Mutilated conductors higher RI on both positive and negative. Positive corona produced single or two or more violent pulses; negative corona rapid succession of impulses. Contamination discussed. Correlation with theory. Positive space charge about conductor as causing corona in negative half-cycle and preventing it positive half-cycle.

40. Miller, Co., "Effect of Atmosphere Contamination on Generated Radio Influence Voltage". AIEE Conference Paper, October, 1956.

Gives curves of variation of RIV as caused by water, iron shot, flyash, silicon carbide, sand, sand dust, alundum, sulphur, and smoke for 1-1 in., 1-2 in. and 2-3/4 in. diameter aluminum tubes. Used Ferris 32 B Meter with 600 ohm NEMA circuit. Found appreciable affect of solid air-borne particles in reducing threshold voltage and some increased RIV level for a given operating voltage. Larger particles caused more pronounced effect. Effects larger for particles of higher conductivity. Water has greater effect than solid particles. Smoke particles sticking to conductor lowered threshold and raised levels.

41. Morgan, Jr., G. A., "Analysis of Loop Probes for use in Measuring Interference Fields". NRL Report R-3486, June 17, 1949.

A small shielded-loop antenna, to be used as a probe for indicating and measuring radio-frequency interference fields from electronic equipment, has been analyzed. The input impedance is similar to an equivalent shorted two-wire, balanced, transmission line. Voltage induced by a field conforms, over the usable frequency range, to that calculated by equations applicable at low frequencies, but the output voltage varies because of the transmission-line effect.

A number of loop-probe designs have been analyzed and found to have undesirable characteristic impedance discontinuities which make calculation of their characteristics almost impossible. A method of calibration, which uses another small shielded loop to establish a radio-frequency field of known characteristics, has been developed, and its accuracy and reliability are proved experimentally. A simplified loop-probe design has been found to be the most satisfactory. Loop probes of the approximate dimensions



of those analyzed have been shown to be usable for the desired application at frequencies below approximately 400 Mc/s only, both because unsatisfactory response characteristics and because of difficulties of calibration at higher frequencies.

42. Newell, H. H. and F. W. Warburton, "Variations in Radio and Television Interference from Transmission Lines", AIEE Trans., Vol. 75, III, June 1956, pp. 420-29.

Paper shows RI and TVI on 33-115 kV lines present. Some sources will give TVI - mostly metal-metal sparking etc. TVI less in rain. Affected by wind. TVI generally can be reduced but RI at low frequencies may require major changes.

43. Pakala, W. E. and Lippert, G. D., "Radio influence from Transmission Lines as Function of Conductor Gradients", AIEE Conference Paper 57-803, 1957.

Compares single and bundle conductors on the basis of equal ratios of critical gradient to gradient for lines, assuming this ratio to be equal for same RI generation. Gives curves based on derived formulae for 40 foot height for 2, 3 and 4 conductor bundles and single conductors of  $kV_{rms} \phi - \phi$  for same RI generation versus Single or Sub-conductor diameter, based on 230 kV nominal and 242 kV maximum for 1 inch diameter conductor. Gives table of line voltages for same RI from these curves and lines in service and proposed.

44. Rorden, H. L., Gens, R. S., "Investigation of Radio Noise as it pertains to the Design of High Voltage Transmission Lines", AIEE Trans. (52-106) Vol. 71, III, 1952, pp. 466-77.

Recording with Coupling Capacitor at 0.82 Mc/s of radio interference from 230 kV lines. Single phase and three-phase comparisons of radio interference on lines.

45. Smith, E. A., "Radio Interference from High Voltage Systems",  
Journal of Franklin Inst., 1934, Vol. 218, p. 653.

Discussion of sources and how to suppress pin type insulators and suspension type insulators. Curves of attenuation for lines 33 to 88 kV for wet and dry weather. Choke coils.

46. Taylor, F. L., C. J. Crockford and R. V. Nicolson, "Investigation of Radio Noise from Existing Lines and Equipment to aid in the Design of Future Extra-High-Voltage Lines," AIEE Trans., August 1957, III, p. 436-445.

A "progress report" on field and laboratory studies. Radiation characteristics of single and bundle conductors all different. Measurements made for most part with Ferris meter on 120 kV Detroit Edison transmission system and 230 kV line of Hydro-Electric Power Commission of Ontario. First with 3/0 copper, 250 MCM copper, 477 MCM ACSR and 795 MCM ACSR conductors and second with 795 MCM ACSR conductors. Also 345 kV AEP and OVEC lines with 1.6 in. and 1.75 in. conductors. All measurements at 1 Mc/s. Test locations at 25 feet from outer conductor parallel for 1 1/2 spans and lateral at mid-span for distances on either side of 100 feet from outer conductor. No local "hot spots" or standing waves detected on 120 and 230 kV lines.

Conducted Measurements. Describes carrier coupling capacitor in NEMA Circuit tests and gives values. Daily variation of conducted measurements: high during day, low during morning hours. Rain: increased conducted measurement from 5000 uv to 6000 uv. Effect of fog and mist. Effect of voltage variation. Method of predicting conducted RIV on operating lines from laboratory results.

47. Adams, G. E., "The Calculation of the Radio Interference Level of Transmission Lines Caused by Corona Discharges," AIEE Transactions Vol. 75, Part III, pp. 411-18.
- 47A. Adams, G. E., "Voltage Gradients on High Voltage Transmission Lines," Paper 55-22, AIEE Transactions, Vol. 74, Part III, April 1955, pp. 5-11.

The voltage gradient is calculated in two steps. First, calculations are made based on conductors of infinite length, suspended above a perfectly conducting flat ground plane, and smooth cylindrical surfaces. The interconductor spacings and to ground are constant and the effects of supporting structures and near-by objects are neglected. Second, the stranding factor,  $F_2$ , is determined and is represented by the ratio of the maximum voltage gradient of the stranded conductor to the maximum voltage gradient of a smooth conductor having the same outside diameter and same charge. Bundled conductors are not considered but the method is applicable providing "equivalent diameter" computations are made. Double circuit calculations are also covered. Computer computations are recommended.

48. Adams, G. E., Poland, M. G., Liao, T. W., Trebby, F. J., "Radio Noise Propagation and Attenuation Tests on Bonneville Power Administration McNary - Ross 345 kV Line", AIEE Transactions Paper 59-49. (1959)
49. Adams, G. E., "Wave Propagation Along Unbalanced High Voltage Transmission Lines", AIEE Transactions Paper No. 59-95. (1959)
50. Aggers, C. V., Foster, D. E., Young, C. S., "Instruments and Methods of Measuring Radio Noise," AIEE Transactions Vol. 59, March 1940, pp. 179-192.
51. "American Standard on Methods of Measurement of Radio Influence Voltage and Radio Influence Field (Radio Noise)." 0.015 to 25 Mc/s, Low Voltage Electric Equipment, and Non-electric Equipment. ASA-C63.4, 1957.
52. Bartenstein, Dpl. Ing. R., and Prof. Dr. Ing. G. Lesch, "Measurement of Corona Losses and Interference Levels at the 400 kV Research Station in Mannheim - Rheinau with Special Reference to Bundle Conductors". Report No. 402, The International Conference on Large Electric Systems, 1956, Vol. III.
53. Bellaschi, P. L., Aggers, C. V., "Radio Influence Characteristics of Electrical Apparatus". AIEE Trans. Vol. 57, 1938, p. 626-33.
54. Burrill, Charles M., "An Evaluation of Radio - Noise Meter Performance in Terms of Listening Experience", Proceedings Institute of Radio Engineers, Vol. 30, October 1942.
55. Cahen, F., Pelissier, R., "Research on Corona Effect at Extra High Voltages - Radio Interference", Report No. 406, International Conference on Large Electric Systems, 1952, Vol. III.

- 55A. Carroll, Joseph S., Cozzens, Bradley, "Corona Loss Measurements for the Design of Transmission Lines to Operate at Voltages Between 220 kV and 330 kV" Paper 32-113, AIEE Transactions, Vol. 52, March 1933, pp. 55-63.

The authors discuss corona loss tests on transmission line conductors and give comparative results of the various conductors noting the effects of scratch brushing, dragging conductors over the ground, and polishing. Discussion comments by William S. Peterson are more noteworthy than the main report where he contended the relative air density factor  $\sigma$  in Peek's formula for  $E_0$  should be  $\sigma^{2/3}$ .

56. Carson, John R., "Radiation From Transmission Lines", Journal of AIEE, 1921, p. 789.
57. Chapin, E. W., Federal Communication Commission, Office of Chief Engr., Technical Research Division, L.D. Report 6.3.1 - "Field Strength Measurements".
- 57A. Clarke, Edith, "Three-Phase Multiple Conductor Circuits," Paper 32-95, AIEE Transactions, Vol. 51, Sept. 1932, pp. 809-823.

Formulas are developed for the inductance and capacitance to neutral per phase and the approximate corona starting voltage of perfectly transposed, multiple conductor, three phase transmission lines having any number of conductors per phase. For certain special arrangements of the conductors, curves are given for the 60 cycle reactance, capacitance, and corona starting voltage.

58. Dinger, Harold E., "Factors Affecting the Accuracy of Radio Noise Meters", Proceedings, Institute of Radio Engineers, (New York, N. Y.), January 1947.
59. Frick, C. W., "A Study of Wave Shapes For Radio-Noise-Meter Calibrations", AIEE Transactions, Vol. 64, 1945, pp. 890-901.
60. Liao, T. W., Keen Jr., W. A., Powell, D. R., "Relationship Between Corona and Radio Influence on Transmission Lines, Laboratory Studies. Part I, Point and Conductor Corona", AIEE Transactions, Paper 57-167.
61. Lippert, G. D., Pakala, W. E., Bartlett, S. C., Sparlin, B. J., "The Radio Influence Characteristics of Bundle and Single Conductors - Tidd Project", AIEE Transactions Paper No. 57-804.

62. "Measurement of Radio Disturbances due to Corona Effect on Extra High Voltage Lines". Part I: Study and Comparison of the Methods Utilized in Different Countries for Radio Disturbance Measurements, F. Cahen, J. Carteron, B. Prokocimer (France). Part II: Measurements on Extra High Voltage Lines of Different Construction, W. S. Price (U.S.A.). Paper No. 416, International Conference on Large High-Voltage Electric Systems, 1956, Part III.
63. "Measurement of Radio Interference In Accordance with Specification MIL-I-6181B using Stoddart NM-20A or NM-20B Equipment". Engrg. Dept. Stoddart Aircraft Radio Co., Inc. Hollywood 38, California.
64. "Methods of Measuring Radio Noise," Report of the Joint Coordination Committee on Radio Reception of EEI, NEMA, and RMA, Edison Electric Institute, New York 1940. EEI Publication No. G9, NEMA 107, RMA Engineering Bulletin No. 32.
65. Merriman, H. O., "Radio Interference Suppression in Canada" - AIEE Paper 47-140, 1947.
66. MIL-I-16910A (Ships) - "Interference Measurement, Radio, Methods and Limits"; 14 kilocycles to 1000 megacycles. 30 August, 1954.
- 66A. Miller, C. J., "Mathematical Prediction of Radio and Corona Characteristics of Smooth Bundled Conductors," Paper 56-520, AIEE Transactions, Vol. 75, Part III, Oct. 1956, pp. 1029-1037.

A mathematical prediction method of arriving at the RIV characteristics of smooth single and bundled conductors from 25 foot lengths of laboratory test models is discussed. A method of computing the unit surface gradient, gm for single smooth and bundled conductors is also discussed. The writer does not propose to apply the calculations directly to actual transmission lines but states that stranding factors and environmental effects must be considered before doing so. Actual surface gradients must also consider the presence of other conductors and rain effects, none of which are discussed.

- 66B. Miller, C. J., Jr., "The Calculation of Radio and Corona Characteristics of Transmission Conductors," Paper 57-165, AIEE Transactions, Vol. 76, Part III, August 1957, pp. 461-475.

A method of calculating the corona and radio interference generating characteristics of either single or bundled transmission line conductors is presented. Calculations are made in six steps. The concept of "equivalent single conductor diameter" representation for bundled conductors is presented and confirmed by test results. The method discussed is readily adaptable to rapid approximation, but more accurate methods should be used if required. The accuracy of the proposed method will be enhanced if the computation of the maximum unit surface gradient is determined when giving consideration to the presence of all conductors.

67. Miller, Charles J., "A Correlation of the Present with a Proposed Standard Method for RIV Measurements on High Voltage Devices". AIEE Transactions, Paper No. 59-80 (1959).
68. National Research Council, Radio and Electrical Engineering Division - "Bibliography on High Voltage Transmission Line Corona and Radio Interference and Fundamental Corona Processes" - Revised 1958 - A.S. Denholm.
69. Ontario Hydro Research News, Vol. II, No. 1, January - March, 1959.
70. Pakala, W. E., and Showers, R. M., "Principles and Application of Radio Interference Measurements" - IRE Transactions on Instrumentation, Vol. 7, Numbers 3 and 4, December 1958.
71. Pelissier, R., "Radio Interference Caused by Extra High Voltage Lines," Bulletin Societe Francaise Des Electriciens, July 3, 1953, pp. 409-18.
72. "A Practical Handbook for Location and Prevention of Radio Interference from Overhead Power Lines," Project NY 411 002-1, Technical Memorandum M-116, U.S. Naval Civil Engineering Research and Evaluation Laboratory, Port Hueneme, California.
- 72A. Price, W. S., Bartlett, S. C., Zabel, E. S., "Lightning and Corona Performance of 330-kV Lines on the American Gas and Electric and Ohio Valley Electric Corporation Systems," Paper 56-231, AIEE Transactions, Vol. 75, Part III, August 1956, pp. 583-597.

A summary of a study involving lightning, corona, and RIV on a number of 132 and 330 kV lines is presented. The importance of cleaning and the proper handling of conductors during line construction is discussed. Methods to accomplish this end are covered. Field measurements for RIV for both lateral and longitudinal are covered. Relative RIV changes were noted when double circuit conductor position arrangements were changed. Shield wires for reduction of telephone line susceptance are discussed. Discussion comments by G. E. Adams on conductor phasing arrangements for double circuit lines are extremely helpful and are adjudged more pertinent to RI" predictions than the actual paper.

73. Proceedings of the Conference on Radio Interference Reduction held at Armour Research Foundation of Illinois Institute of Technology, 1954:
  - (a) 1954 - Problems of Radio Interference Measurements - William Jarva, U.S. Naval Air Development Center, Johnsville, Pa.

- (b) 1954 - Instrumentation for Interference and Field Strength Measurement - J. F. Chappell  
Signal Corps Engrg. Labs. Fort Monmouth, New Jersey.
  - (c) 1954 - Research Investigations of Interference Measuring Instruments - R. M. Showers and A. Eckersley, University of Pa., Philadelphia, Pa.
- 74. Proceedings of the Second Conference on Radio Interference Reduction at Armour Research Foundation of Illinois Institute of Technology - March 1956:
  - (a) IF Amplifiers for Radio Interference and Field Strength Measuring Equipment - P. C. Hayden and R. G. Rullman.
  - (b) Reduction of Power Line Radio Interference - J. C. Senn, U.S. Naval Civil Engrg. Research and Evolution Laboratory, Port Hueneme, California.
- 75. Proceedings of the Third Conference on Radio Interference Reduction at Armour Research Foundation of Illinois Institute of Technology February, 1957:
  - (a) Interference Sources and Effective Reduction Procedures for Power Line Interference - D. B. Wright U.S. Naval Civil Engrg. Research and Evaluation Laboratory, Port Hueneme, California.
- 76. Proceedings of the Fourth Conference on Radio Interference Reduction and Electronic Compatibility at Armour Research Foundation of Illinois Institute of Technology, October, 1958:
  - (a) Receivers for Interference Measurements in the 20-4000 Mc/s Range - M. Levine.
  - (b) Measurement of Electromagnetic Interference on High Voltage (50 kV) Transmission Lines, J. D. Ghesquiere and S. A. Bennett.
  - (c) List of "Recently Issued Reports" - Since January 1, 1957 included.
- 77. Progress Reports by the University of Pennsylvania on "Investigations of the Measurement of Radio Interference on Contract with the Bureau of Ships, United States Navy.
- 78. Renaudin, D., "Measurement of Radio Frequency Caused by High Voltage Lines", Bulletin Societe Francaise Des Electriciens, July 3, 1953, pp. 425-31.

79. Robertson, L. M., Wagner, C. F., Bliss, T. J., "Colorado High-Altitude Corona Tests, Scope, Tests and Instrumentation". AIEE Transactions Paper No. 57-161.
80. Rorden, H. L., "Radio-Noise Influence of 230 kV Lines", AIEE Transactions, Vol. 66, 1947, pp. 677-81, Discussion P. 682.
- 80A. Rutsey, J. P., "Field Measurement Technique for Extremely Low Levels of the Electromagnetic Interference on High Voltage Transmission Lines," Hinchman Corporation, Detroit 1, Michigan.

This paper reports on a study of low-level measurements of electromagnetic interference on high voltage transmission lines performed by the Hinchman Corporation for the Department of the Navy, Bureau of Yards and Docks under contract NBY-24961. The paper deals principally with the development and use of instrument techniques employed in the field and the significant facts determined. Field measurements of electromagnetic interference were obtained by low-level techniques in the frequency range of 20 megacycles/sec to 1,000 megacycles/sec.

81. Senn, J. C., Wright, D. R., "Project NY 411002, Technical Memorandum M-117, Interim Report Studies Leading to the Development of a Radio Interference Filter for Overhead Power Lines". January 4, 1957.
82. Senn, J. C., Gosley, A. W., "Reduction of Power Line Radio Interference", U.S. Naval Civil Engineering Research and Evaluation Lab. U.S. Dept. of Commerce, Office of Technical Services Publication No. PB 111666.
83. Slemon, G. R., "Radio Influence From High Voltage Corona", AIEE Transactions Vol. 68, Part I, 1949, pp. 198-204, Discussion 204.
84. Stone, L. N., Gens, R. S., Gehrig, E. H., "Radio Interference Attenuation on Energized HV Transmission Lines - Measurement and Application". AIEE Transactions Paper 59-814 (1959).
85. Technical Standards Division, "Location of Radio Interference on Rural Power Systems," Rural Electrification Administration, U.S. Dept. of Agriculture, Washington, D.C.
- 85A. Temoshok, M., "Relative Surface Voltage Gradients of Grouped Conductors," AIEE Transaction, Vol. 67, Part II, September 1948, pp. 1583-1591.

This paper compares the surface voltage gradients of 1, 2, 3 and 4 conductor bundles in various transmission line design configurations. Comparison is given in ratios or percents and no actual values are given for the actual gradients. The



effects of number of conductors and intra-group spacing, spacing between phases, conductor diameter, height above ground, presence and non-presence of ground wires, configuration and instantaneous voltage values are discussed.

86. Measurement of Electromagnetic Interference on High Voltage (50 kV) Transmission Lines, J. D. Ghesquiere and S. A. Bennett, Proceedings of the Fourth Conference on Radio Interference Reduction and Electromagnetic Compatability, Armour Research Foundation, October 1958.
87. NAVCERELAB Technical Report R-003, (Project NY 411 002-1), Some Theoretical Considerations Concerning Radiation from Overhead Transmission Lines, By A. M. Intrator, Port Hueneme, California, 28 June 1953.
88. NAVERELAB Technical Memorandum M-095, Interim Report Reduction of Power-Line Radio Interference, by J. C. Senn and A. W. Gosley, Port Hueneme, California, 1 February 1955.
89. Senn, J. C., "Reduction of Power-Line Radio Interference," Proceedings of the Second Annual Conference on Radio Interference Reduction, Chicago, Illinois, March 1956, p. 24.
90. U.S. Department of Agriculture, Rural Electrification Administration, Technical Standards Division, Location of Radio Interference on Rural Power Systems, Washington, D.C., March 1950, 4 pp.
91. Civil Aeronautics Administration, Department of Commerce, Technical Development Note No. 46, Measurements of Noise Radiation from High-Voltage Transmission Lines, by J. M. Lee, May 1947.

AIR FORCE CONTRACT 30-602-3822

APPENDIX VII PART (4)

SUPPLEMENT TO FOREIGN LITERATURE

AUSTRALIA

1960

- 1A. The 330 kV Transmission System in Australia CIGRE Paper 401  
June 1960

Thornton, J. G.

The first stages of the 330 kV Transmission system in Australia have recently been put into service. The authors describe some of the more unusual features of the system and report on the results of commissioning tests and early operating experiences.

Radio noise in relationship to blemishes and contamination on the line is discussed.

CANADA

1963

- 3A. Corona Phenomena from Water Drops on Smooth Conductors under High Direct Voltage. National Research Council  
of Canada, Nov. 1963  
Ottawa

Akazaki, M.

The effect of high direct voltage on the forming and dislodging of water drops hanging from a smooth conductor is shown and is used to explain the resulting corona characteristics, such as pulse amplitude and repetition rate, audible noise, RI and loss current, and corona waveforms. The phenomena occurring during the conductor drying period are also explained. The relationship between number and spacing of points on a smooth conductor on the one hand and RI and loss current on the other is demonstrated. Results obtained from water drop experiments are compared with those obtained in experiments using metal points of various shapes.

### CANADA

1965

- 4A. Power Line Carrier Radiation from High-Voltage Lines

Ontario Hydro Research  
Quarterly Third Quarter  
1965

Jones, D. E.

Power line carriers in the 30 to 200 kc/s range are widely used for protection, control and supervision of power systems. This frequency spectrum is almost saturated with the increasing demand of new systems. Due to the overcrowding, the 200-400 kc/s band which is used for aeronautical and marine radio-navigation purposes is being considered for power line carrier provided that interference from the power lines to the radio services is negligible.

In view of scarcity of accurate measurements it was decided to make actual measurements of the radiation field by use of an aircraft suitably equipped flying near the power line at the same time as similar measurements were made on the ground. Longitudinal and lateral profiles were measured at heights up to 4000 ft.

### DENMARK

- 7A. Calculation of Spark Breakdown of Corona Starting Voltages in Non-Uniform Fields.

Paper No. 31TP66-80,  
Presented at IEEE  
Winter Power Meeting,  
New York, Feb. 1966

Pedersen, A.

A method is described for calculation of breakdown voltages or corona starting voltages more reliably than by means of the rules of thumb methods in common use.

Breakdown criteria such as Townsend's equation and the streamer theories of Loeb and Meek are discussed and semi-empirical quantitative breakdown criterion based on these theories is formulated

### GERMANY

1965

- 49A. Taschenbuch der Funk-Entstörung  
Warner, A.

Textbook printed by  
Vde-Verlag GMBH  
Berlin 1965

### JAPAN

1965

- 70A. 500 kV Line Design (II)  
Corona and RIV Characteristics  
of Insulator Hardware Assemblies  
Saruyama, Y.

Paper submitted to  
IEEE, 1965

This paper describes the corona noise characteristics of insulator-hardware assemblies in the Boso Power Transmission Line of Tokyo Electric Power Co. which is the first 500 kV transmission line in Japan. In this paper are reported the results of corona noise measurement made on V-string insulator assemblies and strain insulator assemblies. The characteristic feature of this paper is that data on the corona noise level of insulator hardware obtained from a test line was converted into the values of the level on actual transmission lines for comparison with conductor corona noise levels and the design of insulator-hardware was decided accordingly.

- 70B. Impulse Noise Voltage in a Transmission  
Line Generated by the Fault.  
Udo, T.

A high frequency noise voltage is generated as a fault occurs in a transmission line. The behavior of the noise is considerably complex and depends greatly on a particular condition of the fault point and the transmission line. The authors measured noise voltages in artificial fault on ten transmission lines (about 200 times of faults) with voltage classes from 33 kV to 275 kV,

1965 Central Research  
Inst. of the Electric  
Power Industry 1229,  
Iwato Komae-Cho,  
Kitatama-Cun.  
Tokyo, Japan.

in addition obtained about 15 records of faults due to actual lightning on an energized 66 kV line. As a result of these investigations and theoretical analysis, it was found out that there is a certain mechanism of noise generation which can well explain the actual situation.

- (1) The narrow band high frequency noise voltage was found to coincide with the calculated value. It was also confirmed both theoretically and experimentally that the noise is considerably large just after the occurrence of the fault, but it attenuates almost completely after a time interval of about 1.5 milliseconds.
- (2) In case of a fault through a cracked pin-type insulator, a remarkably large noise voltage is sometimes generated by the particular voltage-current characteristics of the insulator.
- (3) In arc faults through an air-gap, suspension insulator string or a tree, it was found out that relatively small noise voltage is generated by the arc, except just after an occurrence of fault.
- (4) The data presented will be useful in the design of tele-transmission equipments and fault locators which are receiving a signal from the faulty transmission line.

70C. The Radio-Interference Characteristics of Four-Conductor Bundle: Shiobara 600 kV Laboratory.

Y. Sawada

Paper No. 31CP65-20,  
Presented at IEEE  
Winter Power Meeting,  
New York, Feb. 1965.

It has been required in Japan to construct the power transmission line in two circuits operating at the voltage ranging from 400 kV to 520 kV (line-to-line voltage) for transmission of greater amount of electric energy. At the early stages of planning this new extra-high-voltage (EHV) line, it was recognized that radio interference (RI),

corona loss, insulation and mechanical line design and performance had to be studied. Therefore, the Shiobara 600 kV Laboratory was constructed in order to solve, in advance, these problems, and placed in service on June 1961.

In the range of line voltages above described, it was indicated that the suitable phase conductor was a 4-conductor bundle, with maximum conductor surface voltage gradients (maximum surface gradient) which are approximately equal to those of existing 275 kV lines. Therefore, the test line in Shiobara was constructed to permit the full-scale 3-phase testing of 4-conductor bundle lines at voltages up to 600 kV.

AIR FORCE CONTRACT 30-602-3822 - VOL. III

APPENDIX VII PART 5

SUPPLEMENT TO AMERICAN LITERATURE

4A. Designing Distribution Lines for  
Better Performance

Armstrong, H. R.

Paper No. 31CP66-91,  
Presented at IEEE  
Winter Power Meeting,  
New York, Feb. 1966

A new factor recently injected into the distribution line performance problem is that of appearance. Line designs conceived for better public acceptance, especially those that group the conductors, are often more vulnerable to lightning than cross arm construction. This is serious because for cross arm construction lightning accounts for 40% of the outages. The problem, then, is to reconcile performance with improved appearance while keeping costs within reason.

In this paper the problem is approached from two starting points. The first is an analysis of distribution line troubles. A thorough understanding of the causes of circuit outages can lead to a more realistic appraisal of the electrical and mechanical lightning performance of any design, new or old. The causes of outages are based on experience in the Detroit Edison Company service area. The data for determining the lightning performance of a design were obtained from laboratory impulse tests on distribution line components such as insulators, cross arms, fiberglass reinforced plastic brackets, and such materials in combination. These tests are reported in detail in a companion paper.

- 5A. Progress Report on B.P.A. HVDC Test Line  
Radio Noise and Corona Loss.

Bailey, B. M.

To evaluate parameters necessary to the satisfactory performance of a direct-current, high voltage, overhead transmission line, the Bonneville Power Administration (BPA) constructed a dc power supply and test line at The Dalles, Oregon. Details of the installation and the assumptions employed in the design, are covered in previous papers. This paper covers the statistical analysis of six months' recorded data.

Paper No. 31PP66-403

- 8A. Alternating Current Corona in Foul Weather.  
Part II - Below Freezing Point.

Boulet, L.

After a survey of ice particles formation in the layer of the atmosphere close to ground and their properties, the results of laboratory investigation on corona discharges are presented. Trichel pulses and positive pulseless corona generated by the microscopic ice crystals of the snow covering the conductor, were found responsible for the heavy corona losses. The ice formation is discussed briefly. Results of the laboratory analysis are checked against field tests on the Hydro-Quebec 315 kV transmission system.

Paper No. 31TP65808  
Presented at the IEEE,  
EHV-AC Transmission  
Conference Richmond, Va.,  
October 1965.

The influence of solid precipitation on corona discharges on high voltage transmission lines has been investigated since their existence. Initially the losses of energy have been the main interest and already in 1912 F. W. Peek stated that "the effect of snow is greater than that of any other weather condition." The tests on actual lines have, sometimes confirmed Peek's statement, sometimes did not. Many attempts have been made to find some quantitative relations between atmospheric conditions and corona losses. The effect radio noise came later, but until recently little has been found concerning the nature of corona generation by solid precipitation.



The problem is of great importance specially in Canada, where in some regions, as much as one hundred days of snowfall in a year are registered and where the total yearly snowfall can exceed 150 inches. For this reason, laboratory tests were organized at Laval University with the support of the National Research Council. These tests were done in order to explain the results of several tests performed on the 315 kV lines of Hydro-Quebec.

10A. Lossy Conductors for Attenuation of Power Line Interference.

Clark, D. B.

The installation of overhead and underground lossy power conductors at the Hawaiian Tracking Station, South Point, Hawaii, has been tested, and the results show that the conducted and radiated interference from the power line are greatly reduced. Measurements of attenuated interference covered the frequency range from 14 kHz to 1,000 MHz. A comparison to previously installed lossy lines shows that the Hawaii line, composed of the latest developments in lossy conductors, is the most effective in attenuating interference.

Technical Report  
R444-Y-F006-09-02-201,  
Bureau of Yards and  
Docks, U.S. Naval Civil  
Engineering Laboratory.  
Port Hueneme, California.

12A. Man-Made Noise. Report to the Technical Committee of the Advisory Committee for Land Mobile Radio Services from Working Group 3.

Chairman: Deitz, J.

This report presents new man-made noise data measured in a number of typical environments at 50, 160 and 450 Mc/s. Care has been taken to summarize the discussions that led to the measurement methods and procedures adopted by the Group. Several approaches for determining degradation are included. Also included are recommendations for future research in man-made noise as well as an account of the efforts of the automobile manufacturing industry to suppress radiation from motor vehicles.

F.C.C. Report, 1965.

- 13A. Radio Propagation Above 40 MHz  
Over Irregular Terrain.

Proceedings of IRE,  
1957, P. 1383.

Egli, J. J.

The available statistical wave propagation data on terrain effects as a function of frequency, antenna height, polarization and distance are analyzed and expressed by empirical formulae and in the form of nomographs and correction curves.

- 19A. Television Interference from Lightly-  
Loaded Transmission Line Installations.

Transmission and  
Distribution, Nov. 1965

Hoglund, N. A.

Since the late 1940's, when television burst on a welcoming public, power utilities have found that sparks occurring between metal components of insulators can cause disturbance to broadcast reception. The sparks occur not only from faulty insulators but basically from subjection of the metal connections of insulators to low conductor weights. This article reports the causes of such sparks and describes the experience of the New England Electric System (NEES) in eliminating them. NEES construction designs described herein and found susceptible to creating television interference (TVI) are now obsolete.

Investigations have shown that metal-to-metal sparks cause practically all TVI originating from transmission lines. Self-sustaining sparks may occur at insulators, pole hardware, or any place where potential exceeds 500 volts and corresponding air gaps exceed  $5 \times 10^{-3}$  inches. The associated spark current is normally less than a milliamper (10<sup>-3</sup> ampere) and usually consists of the charging and leakage currents associated with insulators. The following treatise assumes electrically normal and well-maintained equipment and restricts discussion to sparks at insulator metal parts.

- 23A. Electromagnetic Waves and Radiating Systems.  
Jordan, E. C. Textbook printed by Prentice-Hall, Inc., New York, 1950

- 25A. The Effect of Station Radio Noise Sources on Transmission Line Noise Levels.  
LaForest, J. J. Paper No. 31TP65-134, Presented at IEEE Winter Power Meeting, New York, Feb. 1965

During the past 15 years, much attention has been given to the determination of transmission-line radio-noise (RI) levels resulting from conductor corona. Excellent results have been obtained using a theoretical approach based on radio-noise power analysis and modal propagation arguments. It is now appropriate to examine the effect of bus-and-station-equipment corona on transmission-line radio-noise levels. Many of the arguments and techniques used in describing the effects of conductor corona on RI levels can be used directly for the case of corona generated in a station. Examination of the question of whether or not station noise is important to line noise levels is particularly timely now because of the large amount of EHV station apparatus being designed and built, and the interest in uprating stations to higher voltage levels than those for which they were designed. Situations where the radio-noise performance of equipment is used as a quality-control index are not considered in this discussion.

- 35C. A Method for Analysis of Radio Noise-High Voltage Transmission Lines.  
Pakala, W. E. Paper No. 31PP66-407, Presented at IEEE Summer Power Meeting, New Orleans, La., July 1966.
- This paper describes a technique for approximating the effect of various factors on the radio noise level, due to conductor corona, on extra high voltage transmission lines. The technique is essentially a comparison method.

Relations are given in the Appendix for calculating the conductor gradients and results are given in curve form. The

application is intended only for comparison of lines due to radio noise generation by conductor corona on ac lines with conductors ranging only from 0.3 - 1.3 inches radius (1.5 - 3.3 cm), and only for the frequency range from about 0.2 to 1.6 megacycles per second. If a statistical evaluation of an existing line has been made the technique can be used to approximate the radio noise level of another line. A relation is also given for obtaining curves of three phase voltage to conductor radius for the same radio noise generation. Because of possible conductor surface differences and environmental differences, which cannot be too accurately evaluated, care is necessary in any final estimation of the average radio noise level.

- 38A. Vepco 500 kV Line Design-New Insulator and Hardware Aspects.

Rawls, J. A.

New insulator-hardware systems and devices used on the VEPCO 500 kV lines are described. Innovations include certain geometric configurations, 50,000 pound insulators, corona-free clamps, combined stringing and permanent support ground wire sheaves, special clips for corona and RI suppression in insulator joints, and many custom designed fittings.

Paper No. 31CP65-154,  
Presented at IEEE  
Winter Power Meeting,  
New York, Feb. 1965

- 49A. Distribution and Frequency Dependence of Unintentionally Generated Man-Made VHF/UHF Noise in Metropolitan Areas.

Skomal, E. N.

A re-evaluation and analysis of previously published and recently accumulated metropolitan area man-made noise data in the 200 to 500 Mc/s frequency range have been performed. Journal publications and organization reports have been collected and evaluated to obtain expressions for the frequency and distance dependence of radio noise in the vicinity of industrial centers in the United States, Europe, and

IEEE Trans. on Electro-  
magnetic Compatibility,  
Sept. 1965, Vol. EMC7,  
No. 3, p. 263.

the Near East. Unpublished results of noise studies conducted by several investigators in the United States were included to supplement the published data.

For a typical metropolitan area, three well-defined noise zones have been identified which may be called Central, Suburban, and Very quiet. For the innermost Central zone, a further subdivision into Urban and Suburban I zones may be justifiable. Least squares approximations curves have been fitted to the noise power data for the frequency interval 200 to 500 Mc/s. The dependence of noise power  $P_n$  upon frequency and distance from a city has been represented by a quadratic function. The expression for  $P_n$  appears to be in general agreement with most existing data throughout the frequency and range intervals of 70 to 500 Mc/s and 0 to 25 miles.

- 49B. Distribution and Frequency Dependence of Unintentionally Generated Man-Made VHF/UHF Noise in Metropolitan Areas. Part II - Theory.

IEEE Trans. on Electromagnetic Compatibility Dec. 1965, Vol. EMC-7, No. 4, P. 420.

Skomal, E. N.

The frequency and range dependence of unintentionally generated man-made VHF/UHF noise in metropolitan areas may be interpreted by assuming that it is composed of random impulses which have been attenuated by propagation over irregular terrain. Man-made noise power per cycle of bandwidth measured for the frequency interval 150 to 500 Mc/s is shown to possess decrements of -10.4 dB/decade change in frequency and -17.3 to -18.3 dB/range decade which are in good agreement with the measured results.

Comparison of the measured VHF/UHF decrements for unintentionally generated man-made noise in urban and suburban areas with those derived from data which were predominantly of automotive ignition origin supports the conclusion that automotive ignition interference is the major source of man-made noise at these frequencies.

- 49C. Computer Study of a Diversity-Augmented, Vehicular, Radio Communication System in a Man-Made Noise Environment.

Skomal, E. N.

The communication performance in the presence of man-made interference of a multiple terminal, diversity augmented, vehicular, radio relay communication system dispersed throughout a large geographical area has been studied by a computer modeling of the multinode system. The radio relay system operating at UHF in the presence of unintentionally generated man-made radio noise has been evaluated from the viewpoint of message propagation rate and completeness of coverage for varying relay point distributions. The communication performance for several distributions of mobile relays dispersed in a specified operational area of western Europe was examined under the influence of man-made UHF noise generated by 52 urban industrial centers in the region. The effectiveness of message repetition in overcoming the adverse effect of intense man-made noise was measured as a function of relay point density.

IEEE Trans. on Electro-magnetic Compatibility, June 1966, Vol. EMC-8, No. 2, p. 67.

**SUPPLEMENTARY**

**INFORMATION**

1 December 1969

## DISTRIBUTION AND AVAILABILITY CHANGES

IDENTIFICATION	FORMER STATEMENT	NEW STATEMENT	AUTHORITY
AD-812 268 Westinghouse Electric Corp., Pittsburgh, Pa. Final rept. Rept. no. 66-8EO- RADIO-R1-Vol-3, RADC-TR-66-606- Vol-3 Mar 67 Contract AF 30(602)- 3822	No Foreign without approval of Rome Air Development Center, Attn: EMLI, Griffiss AFB, N. Y.	No limitation	RADC, USAF ltr, 14 Jul 69